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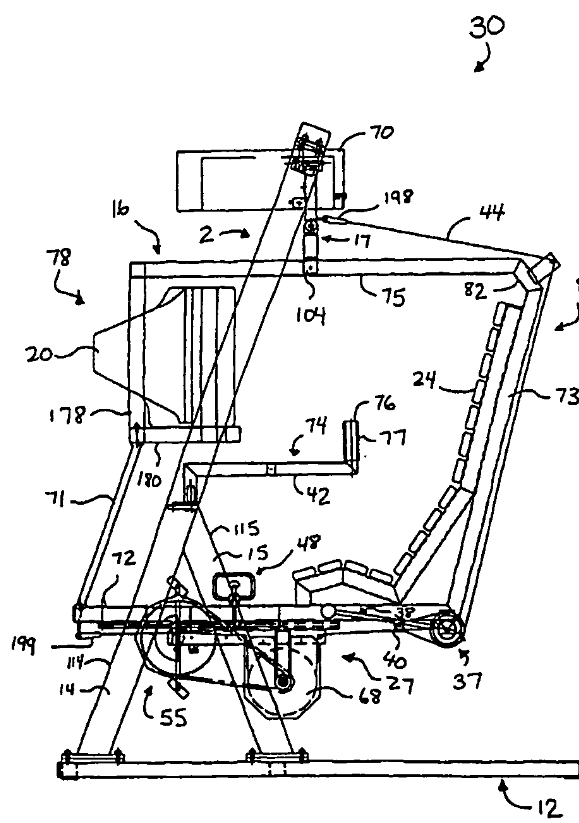
(54) Title: VIRTUAL-REALITY EXERCISE SYSTEM AND METHOD

(57) Abstract

A virtual-reality exercise system (30) includes a computer system (70), visual display system (20), audio system, exercise mechanism (80), unit controls and an adjustable steering mechanism (74). A recumbent bicycle and video display are supported on an inner frame (16) that is suspended from an outer frame via a plural degree of freedom hinge (104), whereby this configuration allows users to move left, right, forward and backward. Adjustable handles (174) provide the user with accurate control over inner frame motion. Control or input devices (74) disposed on the handles permit the user to select from among a series of virtual environments and to interact with those environments. Audio is linked to each virtual environment which are monitored and controlled by the computer system. The computer system basically records all changes within the virtual environment and the user movements within that environment, and provides feedback to the user. Further, the computer system may adjust the virtual environment response to user preference to achieve a balanced workout.



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VIRTUAL-REALITY EXERCISE SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Patent Application Serial No. 60/125,981, entitled "Virtual-Reality Exercise System and Method" and filed March 24, 1999, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Technical Field

The present invention pertains to exercise equipment having the capability of communicating with other exercise units within and across various sites via a communications network. In particular, the present invention pertains to an interactive exercise system and method that provide both cardiovascular workouts and upper and lower body toning. The exercise system or machine includes a computer system, visual display system or monitor, audio system (e.g., typically included with the computer system), exercise mechanism, unit controls and an adjustable steering mechanism. A recumbent bicycle and video display are supported on an inner frame or gondola that is suspended from an outer frame via a two degree of freedom hinge, whereby this configuration allows users to move left, right, forward and backward. The video display moves in tandem with the user, while two adjustable handles provide the user with accurate control over inner frame motion. Control or input devices disposed on the handles permit the user to select from among a series of virtual environments and to interact with those environments.

Audio is linked to each virtual environment which are monitored and controlled by the computer system. The computer system basically records all changes within the virtual environment and the user movements within that environment, and provides feedback to the user. Further, the computer system may adjust the virtual environment in response to user preferences or tendencies so that a balanced

workout is achieved. For example, if the user has a preference for turning to the right, the computer system adjusts the virtual environment to require the exerciser to begin turning left. The exercise system may be configured to communicate, via a communications network, with other machines in a host-supervised environment to provide an interactive workout among a plurality of users. The use of a host minimizes latency and provides a consistent, simple mechanism for modifying virtual environments in response to a plurality of interacting users.

2. Discussion of Related Art

Generally, people utilize a wide variety of techniques to maintain their health and fitness, such as leading a naturally active lifestyle, participating in team or individual sports and/or using exercise equipment within the home or at a facility. Unfortunately, for those not leading a naturally active lifestyle, time and logistics often present problems when trying to schedule time for exercise. These problems are compounded when attempting to coordinate the schedules of several individuals to organize a joint workout. In addition, unpredictable changes in the weather can quickly defeat the best of plans for outdoor activities.

In order to overcome these obstacles, people typically rely on exercise equipment for either strength or cardiovascular training. The exercise equipment is preferably used indoors to overcome the problems caused by inclement or cold weather. Further, the exercise equipment is typically used individually and specifically targets particular muscle groups or cardiovascular workouts, thereby removing the need to coordinate schedules of a group of people and providing an efficient form of exercise. Moreover, the exercise equipment can be placed within the home or at a facility located near the home, thereby removing logistics as a significant obstacle.

In spite of its efficiency and ease of use, exercise equipment is not used as frequently or by as many as expected. The problem relates to motivation since the solitary, routinized workout schedule provided by exercise equipment quickly becomes tedious. For example, people may spend twenty minutes or more running in place staring at the same spot on the wall, or they may be bicycling in place with nothing to divert their attention except a display illuminated by small red bulbs and

other individuals moving between stations in their own solitary, routinized workout schedule. There is nothing interactive, fun or exciting about this efficient form of exercise; people either tolerate it or they quit.

The relevant art has attempted to overcome the aforementioned problems by integrating virtual reality into exercise equipment. For example, U.S. Patent Nos. 5,462,503 (Benjamin et al), 5,466,200 (Ulrich et al) and 5,690,582 (Ulrich et al) disclose an interactive exercise apparatus including an exercise mechanism and a steering mechanism for manipulation by a user to achieve exercise and to indicate a direction of motion. A simulated environment is generated by a computer for display, while the user manipulates the exercise and steering mechanisms to navigate through the simulated environment. The computer monitors the exercise and steering mechanisms to determine user position in the simulated environment. The exercise mechanism may be in the form of a recumbent cycling machine having a seat pivotable about a stationary base to simulate direction changing conditions of a bicycle. In addition, a plurality of apparatus can be networked to permit group participation in the simulated environment.

U.S. Patent No. 5,785,630 (Bobick et al) discloses an interactive exercise apparatus including an exercise mechanism, a steering mechanism and a control mechanism for manipulation by a user to achieve exercise, to indicate a direction of motion and to interact with virtual objects in a simulated environment. The simulated environment, such as a game field, is generated by a computer for display, while the user manipulates the exercise, steering and control mechanisms to travel throughout the simulated environment and interact with virtual objects. The computer monitors the exercise, steering and control mechanisms to determine user position and the position of virtual objects in the simulated environment. The exercise mechanism may be in the form of a stair climbing simulator or a recumbent bicycle having a seat pivotable about a stationary base to simulate direction changing conditions of a bicycle. In addition, a plurality of apparatus can be networked to permit group participation and competition in the simulated environment.

U.S. Patent No. 5,584,700 (Feldman et al) discloses an exercise machine that is used interactively with a video monitor and loudspeaker to create a physical

sensation through a three dimensional environment. The machine includes a recumbent exercise bicycle that has an attached monitor and is suspended from an outer supporting frame by a four bar linkage. The suspended exercise bicycle enables roll, pitch and turning maneuvers, while rate of motion through the environment is achieved by pedaling.

The above described systems suffer from several disadvantages. In particular, the exercise apparatus (i.e., of U.S. Patent Nos. 5462,503; 5,466,200; 5,690,582; and 5,785,630) focus a workout on the particular muscles utilized to manipulate the exercise mechanism, thereby providing virtually no benefit from the workout to other body muscles. Specifically, these systems typically include exercise mechanisms in the form of a stair climbing simulator or a cycling machine. As such, user leg muscles primarily participate in the workout, while other body muscles (e.g., muscles within the arms, chest, shoulder, etc.) receive virtually no benefit. Further, the exercise apparatus cycling machines are configured for limited user maneuverability, thereby impeding realistic simulation of various conditions (e.g., turning, climbing, descending, etc.). Although the Feldman et al machine employs a suspended exercise bicycle for enhanced maneuverability, the exercise bicycle is suspended via a complex four bar linkage. This type of linkage includes several bars and occupies a substantial area, thereby increasing size, complexity and cost of the system. Moreover, the linkage complicates adjustment of the machine leverage (e.g., pitch and roll) and requires a substantial area to permit maneuverability of the suspended bicycle during a workout. In addition, the machine operates only in a stand-alone mode, thereby accommodating only a single user and preventing joint workouts and interaction with users of other machines within the simulated environment.

OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to facilitate an exercise workout that is both physically challenging and mentally interactive.

It is another object of the present invention to facilitate a fun and engaging exercise workout by enabling an exerciser to interact with a multitude of computer-generated and computer-controlled virtual environments.

Yet another object of the present invention is to enable communication between exercise machines via a communications network to enable various users of those machines to participate in a joint and interactive exercise workout.

Still another object of the present invention is to physically and mentally engage an exerciser during an exercise workout via an exercise system.

A further object of the present invention is to suspend an exercise device from a support structure to simulate conditions within a virtual environment and enable a user to navigate through that environment by manipulating the suspended device via various user muscles, thereby enabling muscles of various parts of the user body to participate in and derive benefit from a workout.

Yet another object of the present invention is to suspend an exercise device from a support structure via a pivot assembly having a single hinge with plural degrees of freedom to facilitate pitch and roll motions and simulate conditions within a virtual environment.

The aforesaid objects are achieved individually and/or in combination, and it is not intended that the present invention be construed as requiring two or more of the objects to be combined unless expressly required by the claims attached hereto.

According to the present invention, a virtual-reality exercise system and method is accomplished via an immersive human flight simulator that allows users to maneuver their way through a variety of virtual-reality environments. The exercise system includes a computer system, inner frame or gondola and an outer frame. The inner frame is suspended from the outer frame by a two degree of freedom hinge mechanism that allows users to move left, right, forward and backward. Two adjustable handles enable users to establish accurate control over their movements (e.g., to simulate diving, banking, accelerating or gaining altitude). For example, climbing may be simulated by the user generally pulling the handles toward his/her body, while diving may be simulated by the user pushing the handles away from his/her body. Left and right turning maneuvers may be simulated by alternately pulling on the handles, while speed of the user through the virtual environment is based on the pedaling rate of the user on a pedaling mechanism. The handles include control or input devices that may be programmed for a variety of purposes,

such as shooting bullets or lasers and selecting various virtual environments. Additional virtual environments, preferably implemented by software, may be loaded into the computer system via CD-ROM and an installation procedure similar to that of other conventional or commercially available software applications. Usage of these environments can be tracked by the computer system, thereby allowing the least used environments to be deleted when additional environments become available.

A video display or monitor is attached to the inner frame and positioned directly in front of the user. This results in the video display moving with the user to simulate a remarkably realistic view (e.g., from a space shuttle, fighter jet or hang-glider). The computer system records each user movement and enables the view on the video display to change accordingly. The computer system also measures each user movement, preference and tendency. For example, if a user has a tendency to dive, the computer system subsequently presents the user with changes in the environment that force the user to climb, thereby providing a balanced and effective workout. The computer system may further provide the user with summary feedback, such as calories burned, miles biked, etc.

Pedaling resistance applied to the pedaling mechanism may be varied via a drive train, whereby the pedaling resistance increases when the user climbs and decreases when the user dives. Resistance may also vary when the user turns to the left or right, or may be controlled by the computer system to simulate traversal of various terrains in a virtual environment. The pedaling mechanism may be removed entirely from the exercise system and be replaced with another exercise or rehabilitative mechanism (e.g., stair climbing device, mechanisms for use in a rehabilitation setting, etc.).

In addition, a plurality of exercise machines can be linked via a host server to allow users of the machines to compete against one another in the same virtual environment. This architecture typically requires no time delay and assumes zero latency, whereby the actions taken by one user are assumed to be immediately seen by all other users in that virtual environment. Alternatively, the exercise machine may be in communication with facilities located around the world via an Internet connection with the host server.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of specific embodiments thereof, particularly when taken in conjunction with the accompanying drawings wherein like reference numerals in the various figures are utilized to designate like components.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1a is a side view in elevation of an exercise machine according to the present invention.

Fig. 1b is a top view of the exercise machine of Fig. 1a.

Fig. 2a is a side view in elevation of the exercise machine of Fig. 1a diagrammatically illustrating inner frame fore and aft motion relative to the outer frame according to the present invention.

Fig. 2b is a rear view in elevation of the exercise machine of Fig. 1a diagrammatically illustrating inner frame lateral motion relative to the outer frame according to the present invention.

Fig. 3a is a front view in perspective of the pivot assembly of the exercise machine of Fig. 1a.

Fig. 3b is a side view in perspective of the pivot assembly of Fig. 3a.

Fig. 4a is a side view in elevation of the pedal assembly of the exercise machine of Fig 1a.

Fig. 4b is a front view in elevation of the pedaling mechanism of the pedal assembly of Fig. 4a.

Fig. 4c is a front view in elevation of the flywheel and associated components of the pedal assembly of Fig 4a.

Fig. 5 is a side view in elevation of the inner frame of the exercise machine of Fig. 1a.

Fig. 6 is a block diagram of an exercise system configuration for an individual or stand-alone mode of operation according to the present invention.

Fig. 7 is a block diagram of an exemplary software architecture for the computer system to enable control of a virtual environment in a stand-alone mode of operation according to the present invention.

Fig. 8 is a procedural flow chart illustrating the manner in which the computer system controls the virtual environment in a stand-alone mode of operation according to the present invention.

Fig. 9 is a block diagram of an exemplary exercise system configuration enabling various exercise systems to communicate over a Local Area Network (LAN) according to the present invention.

Fig. 10 is a block diagram of an exemplary exercise system configuration enabling various exercise systems residing on different Local Area Networks (LANs) to communicate with each other over a Wide Area Network (WAN) via a remote Corporate Host or Server according to the present invention.

Fig. 11 is a block diagram of an exemplary exercise system configuration enabling various exercise systems to communicate with each other over a Wide Area Network (WAN) via a remote Corporate Host or Server according to the present invention.

Fig. 12 is a block diagram of an exemplary exercise system configuration enabling various exercise systems to communicate with each other over a Wide Area Network (WAN) via a remote Corporate Host or Server, whereby the computer system of an exercise system further serves as a Local Area Network (LAN) server according to the present invention.

Fig. 13 is a block diagram of an exemplary software architecture for the computer system to enable control of a virtual environment in a multi-player mode of operation according to the present invention.

Fig. 14 is a procedural flow chart illustrating the manner in which the computer system controls the virtual environment in a multi-player mode of operation according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An exercise system or machine employing virtual reality to enhance exercise workouts is illustrated in Figs. 1a - 1b. Specifically, exercise system 30 includes an exercise mechanism 80 for enabling a user to conduct a workout and a computer system 70 to measure user movements and control display of a selected virtual environment (e.g., game, course of travel, etc.). Exercise mechanism 80 includes an

outer frame 2 and an inner frame or gondola 16. Outer frame 2 includes a base 12, suspension bars 14, 114 (Fig. 2b) and braces or brackets 15, 115. A series of outer frame bars 3, 5, 7 and 11 is arranged and interconnected to form the base. In particular, bars 3 and 7 are arranged in parallel relation, while outer frame bar 5 is disposed between and extends substantially perpendicular to the distal ends of bars 3, 7. Similarly, outer frame bar 11 is disposed between bars 3, 7 toward the base intermediate portion, and extends between bars 3, 7 substantially parallel to outer frame bar 5. Suspension bars 14, 114 are connected to the respective distal ends of bars 3, 7 and extend upward at an angle slightly less than ninety degrees relative to the base. A corresponding bracket 15, 115 is connected to and disposed between each suspension bar and the base to provide additional support to the outer frame. The brackets respectively extend from the intermediate portions of outer frame bars 3, 7 proximate the junctions where the ends of bar 11 interface bars 3, 7. An elevated bar 19 is connected to and disposed between the upper portions of suspension bars 14, 114, while computer system 70 is suspended from bar 19 to simulate the virtual environment. Elevated bar 19 is typically attached to suspension bars 14, 114 and oriented at angle (e.g., tilted) such that the transverse axis of bar 19 is substantially parallel to the transverse axes of the suspension bars. A conventional wiring harness (not shown) is attached to elevated bar 19 and/or suspension bars 14, 114 to connect computer system 70 to the mechanical and electrical components of exercise system 30 and to an external power source (not shown).

Handles 74, 174 are pivotably attached to the intermediate portions of suspension bars 14, 114, respectively, and each include a corresponding elongated handle extension 42, 142 and a gripping portion 77, 177. Extensions 42, 142 each extend from a respective suspension bar, while gripping portions 77, 177 each extend from the distal end of and substantially perpendicular to a respective extension 42, 142. Handles 74, 174 each further include a corresponding control button 76, 176 typically disposed on the top surfaces of gripping portions 77, 177 to control system operation as described below.

Inner frame 16 is suspended from outer frame 2 via a pivot assembly 17 that is attached to elevated bar 19. Inner frame 16 includes a base rail 72, intermediate rail 73 and suspension rail 75. Suspension rail 75 is slidably coupled to pivot assembly 17 via a fastener 104 to suspend inner frame 16 from the outer frame. Fastener 104 is preferably implemented by a conventional fastener having a set screw or pin mechanism to lock the inner frame into a desired position. Suspension rail 75 is disposed through and in slidable relation with fastener 104, whereby the inner frame position may be adjusted via the fastener to set a desired center of gravity for the inner frame as described below. Intermediate rail 73 is disposed between the suspension and base rails, while base rail 72 includes a seat 24, tension adjustment mechanism 37 and a removable pedal assembly 27. The pedal assembly generally slides onto the distal end of base rail 72 and includes mechanisms for providing variable drag for an exercising user based on the particular position of the inner frame and desires of the user. A coupling rail 82 is disposed between suspension rail 75 and intermediate rail 73, while the intermediate rail is directly connected to base rail 72. The coupling rail is oriented at an angle to interconnect the intermediate and suspension rails.

A monitor frame78 is suspended from the distal end of suspension rail 75 to support a monitor 20 on the inner frame. The monitor frame basically includes a frame extension 178, a platform 180 and a support bar 71 that collectively support monitor 20. The frame extension is connected to the distal end of suspension rail 75 and extends toward base 12, while platform 180 is connected to the distal end of extension 178 and extends toward intermediate rail 73. The extension and platform each include a series of bars typically arranged in a generally rectangular configuration, whereby the platform is disposed substantially perpendicular to the extension distal end to form a ledge that supports monitor 20. Support bar 71 is connected to and disposed between base rail 72 and platform 180 to provide further support for the monitor. The monitor may display an interactive game or virtual environment, such as a view typically observed during a game or when looking through a window.

Referring to Figs. 2a - 2b, a user manipulates handles 74, 174 and corresponding control buttons 76, 176 to interact with computer system 70. Specifically, manipulation of handles 74, 174 toward monitor 20 causes the inner frame to pivot and point in a downward direction, while manipulation of the handles toward intermediate rail 73 enables the inner frame to pivot and point in an upward direction (Fig. 2a). This motion enables simulation of diving and climbing in a virtual environment. For example, when the inner frame is pivoted in an upward direction, monitor 20 displays a view reflecting an upper portion of a virtual environment (e.g., the sky), while manipulating the handles to pivot the inner frame in a downward direction causes monitor 20 to display a lower virtual environment portion (e.g., the ground). Further, individually manipulating handles 74, 174 in a lateral direction enables the inner frame to roll transversely between suspension bars 14, 114 (Fig. 2b). In response to this lateral motion, the computer system simulates a turning motion within the virtual environment proportional to the amount of roll of inner frame 16. Motion to traverse the virtual environment is provided via pedal assembly 27, whereby the rate of travel through the virtual environment is proportional to the rate of pedaling.

Pivot assembly 17 for enabling inner frame 16 to pivot in response to manipulation of handles 74, 174 is illustrated in Figs. 3a - 3b. Specifically, pivot assembly 17 includes a roll pivot support 4, roll pivot shaft 6, roll pivot sensor 8, coupling rod 9, pitch pivot sensor assembly 10, pitch pivot shaft 112 and pitch pivot support 18. Pivot assembly 17 is attached to elevated bar 19 of outer frame 2 to suspend the inner frame from the outer frame. Roll pivot support 4 extends from elevated bar 19 and includes a platform 102 and a pair of substantially parallel supports 86, 88 spaced apart a slight distance. The supports are each generally rectangular and have a rounded distal portion. The length of support 88 is greater than the length of support 86 such that platform 102 is disposed at the proximal ends of the supports and oriented at an angle similar to the angle of orientation of elevated bar 19. The platform may be attached to elevated bar 19 via any conventional or other fastening techniques, whereby the angled platform enables the pivoting assembly to interface the elevated bar. Supports 86, 88 each extend from

platform 102 and include an opening defined toward their distal ends for receiving roll pivot shaft 6. A casing 116 is disposed over roll pivot shaft 6 and extends between supports 86, 88. The proximal end of coupling rod 9 extends through an opening defined in the casing and is rotatably attached to roll pivot shaft 6, while the coupling rod distal end is rotatably attached to the proximal portion of pitch pivot support 18.

Pitch pivot support 18 includes a pair of substantially parallel supports 83, 85 spaced apart a slight distance. The supports are each generally rectangular and have a rounded proximal portion. Pitch and roll pivot supports 4, 18 are oriented orthogonal to each other to enable the coupling rod to rotate about either roll pivot shaft 6 or pitch pivot shaft 112 in response to inner frame motion. Thus, roll and pitch motions of the inner frame are isolated by the pivot assembly for independent measurement. Supports 83, 85 have substantially similar lengths and each include an opening defined toward their proximal ends for receiving pitch pivot shaft 112. A casing 118 is disposed over pitch pivot shaft 112 and extends between supports 83, 85. The distal end of coupling rod 9 extends through an opening defined in the casing and is rotatably attached to pitch pivot shaft 112. The pitch pivot support distal end receives suspension rail 75 of inner frame 16 between supports 83, 85 such that the suspension rail is in slidable relation with pitch pivot support 18 via fastener 104 (Fig. 1a) as described above. Pitch pivot support 18 further includes dividers 120, 122 that are connected to and disposed between supports 83, 85, whereby divider 120 is positioned below casing 118, while divider 122 is positioned toward and above suspension rail 75. The dividers basically strengthen the pitch pivot support, while divider 122 further serves as a stop for engaging the suspension rail. The inner frame is manipulated relative to fastener 104 as described above such that the coupling rod is generally aligned with the center of gravity of the inner frame and user seat to enable the inner frame to hang in approximately the same position whether or not a user is seated on the inner frame.

Roll pivot sensor 8 is preferably implemented by a conventional encoder, such as those having a rotatable encoder disk (e.g., typically including bands disposed on the disk) and associated components (e.g., light emitters and detectors) to detect

rotation of the encoder disk. Basically, the encoder disk is disposed between the light emitters and detectors, whereby rotation of the disk enables the disk bands to prevent the light detectors from detecting emitted light. The light detector generates pulsed signals that may be utilized to determine disk rotation. Roll pivot sensor 8 is typically mounted, via a bracket 124, to coupling rod 9 below roll pivot shaft 6 and on a coupling rod surface facing support 88. The roll pivot sensor includes a pulley - type member 92 attached to a distal end of an encoder shaft 91 that is connected to and extends from the roll pivot sensor encoder disk. Roll pivot shaft 6 similarly includes a pulley-type member 90 disposed proximate support 88. Pulley members 90, 92 are interconnected via a belt 94. Pulley 90 is typically stationary and attached to support 88 via a bolt 21, while belt 94 is fastened about pulley 90 via a bolt 23. When a user manipulates handles 74, 174 to enable lateral or transverse motion of inner frame 16, the proximal end of coupling rod 9 rotates about roll pivot shaft 6, thereby enabling belt 94 to traverse pulley member 92. The belt motion enables pulley member 92, shaft 91 and the encoder disk to rotate, whereby roll pivot sensor 8 measures the rotation of the encoder disk and hence, inner frame lateral motion, and provides a signal to the computer system, via the wiring harness, indicating the roll angle (e.g., the angle of rotation of the inner frame about an axis extending parallel to roll pivot shaft 6) of the inner frame motion. The computer system utilizes the information to update the simulation.

Similarly, pitch pivot sensor 10 is preferably implemented by a conventional encoder as described above having a rotatable encoder disk and associated components to detect encoder disk rotation. Pitch pivot sensor 10 is typically mounted, via a bracket 126, to coupling rod 9 above pitch pivot shaft 112 and on a coupling rod surface facing support 85. The pitch pivot sensor includes a pulley-type member 93 attached to a distal end of a shaft 96 that is connected to and extends from the pitch pivot sensor encoder disk. Pitch pivot shaft 112 includes a pulley-type member 95 disposed proximate support 85. Pulley members 93, 95 are interconnected via a belt 97. Pulley 95 is typically stationary and attached to support 85 via a bolt 127, while belt 97 is fastened about pulley 95 via a bolt 28. When a user manipulates handles 74, 174 to enable fore and aft motion of inner frame 16,

the distal end of coupling rod 9 rotates about pitch pivot shaft 112, thereby enabling belt 97 to traverse pulley member 93. The belt motion enables pulley member 93, encoder shaft 96 and the encoder disk to rotate, whereby pitch pivot sensor 10 measures the rotation of the encoder disk, and hence, inner frame fore and aft motion, and provides a signal to the computer system, via the wiring harness, indicating the pitch angle (e.g., the angle of rotation of the inner frame about an axis extending parallel to pitch pivot shaft 112) of the inner frame motion. The computer system utilizes the information to update the simulation. In effect, the pivot assembly measures inner frame motion in two orthogonal degrees of freedom.

The exercise system generally provides exercise in the form of upper body pitch/roll motion and lower body pedaling. The pivot assembly suspends the inner frame and user from the outer frame, whereby the force required to initiate inner frame motion is proportional to the product of the sine of the absolute value of the angle of motion (e.g., $\sin|x|$, where x is the pitch or roll angle of motion, typically in the approximate range between 0 and +/- 90 degrees) and the combined weight of the inner frame and user. Since an increasing angle of motion provides a greater sine value, a greater force is required as the angle of motion increases. Further, greater effort can be exerted by a user when the arms work in cooperation (e.g., as in a bench-press exercise) to point the inner frame upward or downward, as opposed to single arm manipulation required to cause turning motions (e.g., transverse motion of the inner frame). Accordingly, the pivot assembly functions to require greater effort for pitch (e.g., fore and aft) motions and less effort for roll (e.g., transverse) motions. The variance in effort is accomplished by distancing the roll and pitch pivot shafts from each other by several inches. In particular, the roll pivot shaft is disposed toward the coupling rod proximal end proximate elevated bar 19, while the pitch pivot shaft is disposed toward the coupling rod distal end toward suspension rail 75. Thus, the inner frame traverses a greater pitch angle for an amount of user arm movement than roll angle. In other words, since angle and effort are directly related, inner frame pitch motion is harder to initiate than roll motion.

Lower body exercise is provided by a pedal assembly removably attached to the inner frame as illustrated in Figs. 4a-4c. Specifically, pedal assembly 27 includes

pedal assembly frame 26, flywheel 68 and pedaling mechanism 55. Pedal assembly frame 26 includes an engagement bar 32 and a frame support 33 attached to the underside of the engagement bar. A housing 51 is attached to and extends down from the proximal portion of frame support 33 and houses flywheel 68. The flywheel is disposed between flywheel supports 64, 65 that are attached to the frame support proximal portion between guides 143, 144. The guides direct a tension strap about the flywheel to provide pedaling resistance as described below. The flywheel supports extend down from opposite sides of the frame support along the housing exterior surface substantially in parallel, while a fastener 43 is mounted on a top surface of a stop 133 connected to and disposed between the upper portions of the flywheel supports. The fastener includes a channel 29 configured to engage a groove defined on each side of frame support 33 to secure the flywheel to the frame support.

Flywheel 68 is generally in the form of a disk having a projection 140 extending from a flywheel intermediate portion toward support 65. The projection serves to increase flywheel weight for enhanced balance during rotation. A shaft 87 is connected to the flywheel and extends transversely through the approximate center of the flywheel to define a flywheel axis of rotation. Supports 64, 65 include respective compartments 67, 69 disposed toward the distal ends of those supports. The compartments extend outward from the supports, and include bearings 66 that are disposed proximate the ends of shaft 87 to rotatably secure the flywheel to supports 64, 65. A driver cog or sprocket 62 having a series of teeth 158 extending from the cog peripheral edge is connected to shaft 87 and disposed proximate compartment 67 external of housing 51.

Pedaling mechanism 55 is disposed toward the distal end of frame support 33 and includes a chain ring 58, pedal cranks 52, 53, pedals 56, 57 and a bottom bracket 50. Chain ring 58 has dimensions slightly greater than the dimensions of flywheel 68, and includes a series of teeth 59 extending from the chain ring peripheral edge. Pedal crank 53 is directly attached to the chain ring toward the chain ring center portion, whereby pedal 57 is rotatably connected to the pedal crank distal end. Bottom bracket 50 is attached to chain ring 58 toward the chain ring

center portion such that the chain ring is disposed between pedal crank 53 and bottom bracket 50. Bottom bracket 50 is preferably implemented by a conventional bottom bracket utilized for bicycles, and is disposed through frame support 33 via a channel (not shown) defined in the frame support.

A fastener 61 is mounted on the top surface of bottom bracket 50, whereby the fastener is substantially similar to fastener 29 described above and includes a channel 63 configured to engage the frame support grooves and secure pedaling mechanism 55 to the frame support. Pedal crank 52 is connected to and extends from the bottom bracket, whereby pedal 56 is rotatably connected to the distal end of crank 52. Bottom bracket 50 rotates in tandem with manipulation of pedals 56, 57 and cranks 52, 53 to rotate chain ring 58. A chain 60 is disposed about and between chain ring 58 and cog 62 of flywheel 68, whereby the chain is engaged by the teeth of the chain ring and cog. Rotation of chain ring 58 enables rotation of flywheel 68 such that the flywheel may regulate pedaling as described below. A casing 159 houses chain ring 58, chain 60 and cog 62 to isolate these components from the user.

A proximity sensor 54 is mounted within housing 159 proximate chain ring 58, while an associated wire connector 154 extends from the proximity sensor through housing 159 to enable communication between the proximity sensor and the computer system. The proximity sensor is preferably implemented by a conventional magnetic type sensor, and is utilized to determine the rate of pedaling of a user. Specifically, a metallic plate 89 is attached to a surface of chain ring 58 that is in facing relation with proximity sensor 54. The plate is disposed toward the central portion of the chain ring, and is generally semi-circular having a partial opening to accommodate bottom bracket 50. The plate is partially disposed about the bottom bracket and extends from the chain ring central portion for approximately half the distance between that central portion and the chain ring peripheral edge. Proximity sensor 54 repeatedly detects the plate as the plate rotates about bottom bracket 50 in tandem with rotation of chain ring 58, and provides a signal indicating the quantity of revolutions for a given time interval or, in other words, the rate of pedaling, to the computer system via the wiring harness.

Pedal assembly 27 slideably engages inner frame 16 via guide rail or track 39 (Fig. 5) such that the assembly may be adjusted to accommodate various users. Specifically, a quick-release mechanism 48 is attached to engagement bar 32 to enable adjustment of the pedal assembly. The quick-release mechanism includes supports 168, 170, a pin 79 with a grasping member 160, a pin receptacle 81 and a handle 45. Supports 168, 170 are connected to opposite sides of the engagement bar and extend upward to interface pin receptacle 81. The pin receptacle includes a substantially central opening for receiving pin 79. A handle 45 is connected to the pin receptacle and provides a loop structure for enabling a user hand to manipulate pin 79 via pin grasping member 160. The pin is manipulable along its longitudinal axis and extends through receptacle 81 to interface a series of openings defined in base rail 72. The pedal assembly is initially placed onto the distal portion of the base rail, whereby a user may grasp handle 45 and manipulate pin 79 toward the handle upper portion to enable the pedal assembly to be maneuverable along the base rail. The pedal assembly is positioned in a suitable location along base rail 72, whereby the pin is permitted to engage a base rail opening and secure the pedal assembly into a desired position.

Pedaling resistance of the pedal assembly may be selectively varied by a tension adjustment mechanism as illustrated in Fig. 5. Specifically, tension adjustment mechanism 37 is attached to base rail 72 and includes a tension adjustment cam 36, a tension adjustment sensor 40 and an adjustment handle 38. A tension strap mount 46 is attached to an intermediate portion of coupling rod 9, while a tension strap terminal 49 is attached to the distal portion of base rail 72. The strap mount and terminal are generally implemented by conventional fasteners having an eyelet or other engagement device. A strap 44 is secured to the inner frame and typically includes clips 198, 199 to interface the strap mount and terminal eyelets, respectively.

A tension strap support 47 is attached to coupling rail 82 and includes a projection 197 extending outwardly and having an opening defined therein to receive strap 44. Tension adjustment cam 36 is connected to the proximal portion of base rail 72 via a bracket 25, while tension adjustment handle 38 is attached to cam 36 to

enable selective rotation of the cam and adjustment of tension applied to strap 44 as described below. Handle 38 is preferably implemented by a rod 150 that extends from cam 36 and includes a gripping portion 141, such as a ball, disposed toward the handle proximal end. The cam typically includes a hook or post 35 and a guide 31 to engage and direct strap 44 toward pedal assembly 27. Pedal assembly frame 26 is disposed below base rail 72 and provides lower body exercise in the form of pedaling as described above. The pedaling assembly frame is typically removably attached to and maneuverable along the base rail via guide rail or track 39 attached to the underside of the base rail.

Strap 44 engages mount 46 via clip 198 and extends through the opening in support 47 and along intermediate rail 73 to cam 36. Post 35 engages strap 44, whereby the strap extends over guide 31 and through the pedal assembly to terminal 49. In particular, strap 44 extends from cam 36 and is directed by guide 143 to traverse the peripheral edge of flywheel 68. The strap subsequently encounters guide 144 and is directed toward the base rail distal end to engage terminal 49 via clip 199. Manipulation of handle 38 toward intermediate rail 73 rotates cam 36, thereby causing post 35 to force a portion of strap 44 downward and increase the length of the strap path between mount 46 and terminal 49. The longer path length stretches or increases tension within the strap, whereby the increased tension enhances the frictional forces between the strap and flywheel. The frictional forces impede flywheel rotation, thereby providing increased resistance for pedaling. Conversely, manipulation of handle 38 toward base rail 72 rotates cam 36 in a manner to cause post 35 to manipulate a portion of strap 44 upward and reduce the strap path length. The decreased path length reduces stretching of and decreases tension within the strap. The decreased tension reduces the frictional forces between the strap and flywheel, thereby providing decreased resistance for pedaling.

Tension adjustment sensor 40 is attached to the underside of base rail 72 distally of cam 36 via a bracket 151, and is preferably implemented by a conventional encoder such as those having an encoder disk and associated components to detect disk rotation as described above. The tension adjustment sensor includes a pulley-type member 34 and an encoder shaft (not shown) that is connected to and disposed

between the encoder disk and pulley. A belt 41 is disposed about and extends between cam 36 and pulley 34 to enable the tension adjustment sensor to measure cam rotation. In particular, manipulation of handle 38 causes cam 36 to rotate, thereby enabling belt 41 to traverse and rotate pulley 34. The pulley rotation causes the encoder shaft and disk to rotate, whereby the tension adjustment sensor measures the encoder disk rotation and provides a signal to the computer system, via the wiring harness, indicating cam rotation, and hence, a strap tension. The computer system subsequently updates the simulation in response to the tension signal.

In addition, tension may automatically be applied to strap 44 when a user manipulates inner frame 16 to alter the pitch angle. In particular, strap 44 extends from mount 46 disposed above the pitch axis (e.g., the pitch pivot shaft) to terminal 49 as described above. Accordingly, the pitch position of the inner frame relative to a stationary point above the pitch axis affects the tension applied to the strap. For example, manipulating the inner frame forward to simulate climbing increases the strap path length, thereby increasing the tension applied to strap 44 and the pedaling resistance. Conversely, manipulating the inner frame rearward to simulate diving decreases the strap path length, thereby decreasing the tension applied to strap 44 and the pedaling resistance. Thus, tension may be regulated by a user via handle 38, or be automatically varied based on manipulation of the inner frame.

Alternatively, pedaling resistance may be applied and controlled in various manners by use of a resistance mechanism. The mechanism may be coupled to the flywheel either directly (e.g., sharing an axle) or indirectly (e.g., reduction gears, chain, belt, etc.) to impede flywheel rotation. The manner in which the resistance mechanism is coupled to the flywheel is based on the optimum operating rate (e.g., revolutions per minute) of the resistance mechanism. Computer system 70 determines the amount of resistance to apply to the pedal assembly based on the simulation, and generates a signal (e.g., a voltage proportional to the determined resistance) via hardware (e.g., an interface card) to control the resistance mechanism. The signal may be amplified and transmitted to the resistance mechanism to apply the appropriate resistance to pedaling. This configuration

enables the exercise system to simulate the resistance encountered in the various virtual environments due to differing terrains. For example, the computer system may increase applied resistance to simulate muddy or steep terrains in a virtual environment.

The resistance mechanism may be implemented by various devices. For example, the mechanism may include a conventional alternator having a rotor and stator. Current applied to the stator creates a magnetic field through which the rotor rotates. The rotor is typically connected to ground through a resistor (e.g., one ohm), and is further coupled to flywheel 68. The magnetic field impedes rotor motion, thereby providing increased resistance to the flywheel and pedaling mechanism. Computer system 70 transmits signals to the alternator to control the intensity of the magnetic field, and hence, pedaling resistance based on the simulation as described above. It is to be understood that the functions of the rotor and stator may be reversed (e.g., the rotor provides the magnetic field through which the stator rotates) to control pedaling resistance in a manner similar to that described above.

The resistance mechanism may alternatively include a magnetic particle brake. In particular, current applied to the particle brake charges a magnetic fluid through which blades attached to a brake axle traverse. The brake axle in turn is coupled to flywheel 68, whereby voltage applied to the brake controls viscosity of the fluid. Increased fluid viscosity impedes axle and flywheel rotation, thereby increasing pedaling resistance. Computer system 70 transmits signals to the brake in accordance with the simulation to control the viscosity of the fluid, and hence, the resistance applied to flywheel 68 and the pedaling mechanism.

Another device for use in the resistance mechanism may include an electrically conductive disk that rotates about an axle coupled to flywheel 68. Current is applied to the resistance mechanism to create a magnetic field in which the disk rotates. The magnetic field produces eddy currents within the disk that, in combination with the magnetic field, impede disk and flywheel rotation. Increased intensity of the magnetic field produces a greater charge or eddy current in the disk and impedes disk and flywheel rotation, thereby providing increased resistance for pedaling. Computer system 70 transmits signals to the resistance mechanism to

control the eddy current and intensity of the magnetic field, and hence, the resistance applied to the flywheel and pedaling mechanism.

A conventional servomotor having a stator and servo may further be utilized in the resistance mechanism to control resistance. Specifically, the servomotor is coupled to flywheel 68 and rotates at a speed that is proportional to an input (e.g., voltage) signal. When the user attempts to pedal at a rate greater than the rate of the servomotor, the servomotor impedes rotation of the flywheel, thereby increasing pedaling resistance. The resistance applied by the servomotor to the flywheel is a function of the intensity of the magnetic field of the stator and the distance from the desired reference position of the servo. The input signal is provided by computer system 70 to control pedaling resistance based on the simulation. It is to be understood that any electrical, mechanical or electro-mechanical device, such as hydraulic or pneumatic systems, may be utilized to provide a resistance to the pedaling mechanism. The devices may be coupled to the flywheel, chain ring or other suitable component of the pedal assembly to control pedaling resistance.

The exercise system may operate in an individual or stand-alone mode or be in communication with other exercise systems and operate in a multi-player or networked mode. An exercise system configuration for individual or stand-alone operation is illustrated in Fig. 6. Specifically, exercise mechanism 80 communicates and functions in combination with computer system 70 to provide exercise or game play as described above. The user interaction with a variety of virtual environments is completely controlled by this configuration. Computer system 70 of the exercise system may be implemented by any conventional computer system (e.g., IBM - compatible, Apple, Silicon Graphics, Sun, etc.) preferably having three dimensional graphics, communications and audio (e.g., sound card, speakers, etc.) capabilities.

An exemplary software architecture for stand-alone operation to enable the computer system to control the virtual environment in response to user interaction is illustrated in Fig. 7. Specifically, the software architecture includes a Game Manager module 182, an Artificial Intelligence (AI) Object Manager module 184, a Collision Manager module 186, a Local Object Manager Module 188 and a Display Manager Module 190. Computer system 70 includes an operating system (e.g., Windows 98,

Windows NT, etc.) and a simulation development environment (e.g., SimStudio available from N-Dimension, Inc.) that, in combination, provide an environment to execute the software. Game Manager module 182 receives information from the various exercise system sensors and input devices (e.g., tension adjustment sensor, roll pivot sensor, pitch pivot sensor, proximity sensor, etc., and information relating to weapons use or other acts associated with interaction via the control buttons) and the AI and Local Object manager modules, and is generally responsible for controlling game play or simulation (e.g., including adjustments to the virtual environment based on user tendencies as described above and providing summary feedback) and display of items within the various virtual environments. The sensor measurements are received via the wiring harness by a hardware interface device (e.g., hardware interface card) within computer system 70 that converts and provides the information to Game Manager module 182. The hardware interface device may also transmit signals to the exercise mechanism to control the workout (e.g., signals may be transmitted to the resistance mechanism to control pedaling resistance as described above).

The Game Manager module subsequently distributes information to Artificial Intelligence (AI) Object Manager module 184 (e.g., in the form of game or simulation status information), Local Object Manager module 188 (e.g., in the form of game or simulation status information) and Display Manager module 190 (e.g., in the form of display type information). The AI Object Manager module processes the status information and maintains the position and status of virtual or computer - generated competitors in the virtual environment (e.g., a user may compete against the computer in the virtual environment in the stand-alone mode of operation). The information relating to the position, speed and other characteristics of the virtual competitors is further transmitted to Collision Manager module 186. The Local Object Manager module determines the position, speed and other characteristics of the user within the virtual environment and provides this information to the Collision Manager module. The Collision Manager module processes the information received from the AI and Local Object Manager modules and determines whether or not a collision has occurred (e.g., crashing into a virtual object) and the forces resulting

from a collision (e.g., to assess user damages, point loss or other simulation parameters). The determined forces are returned to the AI and Local Object Manager modules 184, 188, whereby these modules each determine and transmit information to Game manager module 182 (e.g., information relating to game or simulation status) and Display Manager module 190 (e.g., information relating to object position, orientation, status, etc.). The Game Manager module utilizes the received status information to update the simulation. The Display Manager module receives the display type information from the Game Manager module and the object information from the AI and Local Object Manager modules, and processes the information to display the virtual environment scene on monitor 20 (Fig. 1a). Basically, the Display Manager module retrieves the scene geometry and textures from memory and processes the object position and orientation information to create the displayed image. In addition, the Display Manager module provides audio associated with that environment to the user during the workout.

The manner in which computer system 70 processes information from the exercise mechanism to control the virtual environment in a stand-alone mode of operation is illustrated, by way of example only, in Fig. 8. Specifically, a user selects a virtual environment and starts exercising at step 181. Game Manager module 182 (Fig. 7) receives the measurements and user interaction from the exercise mechanism via the hardware interface device at step 183, and provides information to the Display Manager and AI and Local Object Manager modules as described above. The AI and Local Object Manager modules, at step 185, determine the speed, position and other characteristics of users and objects within the virtual environment and provide that information to the Collision Manager module as described above. The Collision Manager module, at step 187, determines whether or not a collision has occurred based on the received information. If a collision has occurred, the Collision Manager module determines the forces resulting from that collision at step 189 and returns information relating to the forces to the AI and Local Object Manager modules as described above. The AI and Local Object Manager modules process and transmit information to the Game Manager module to update the simulation and to the Display Manager module for display of the virtual

environment scene with associated audio at step 191. The workout status is ascertained by the Game Manager module, and if the workout is determined to be complete (e.g., goal attained, time expired, etc.) at step 193, the Game Manager module provides summary feedback information to the user and terminates the workout. Otherwise, new measurements are retrieved from the exercise mechanism at step 183 and the above-described process is repeated.

An exemplary configuration enabling various exercise systems to communicate over a Local Area Network (LAN) for multi-player operation is illustrated in Fig. 9. Specifically, each exercise system 30 is configured to have its computer system 70 communicate with a local server 98. The local server receives position, direction, speed and other information relevant to game or exercise interaction from each computer system 70, and distributes the information to the other computer systems 70 in communication with the local server. The local server coordinates this process and ensures that each exercise system 30 (e.g., computer/ exercise mechanism pair 70, 80) sends and receives the necessary information to perform the simulation. The local server further sends and receives information from each exercise system 30 regarding changes in the virtual environment. During this communication over the LAN, each computer system 70 is communicating with its associated exercise mechanism 80 to deliver information received from the local server and to collect information (e.g., exerciser's speed, direction, etc.) from that exercise mechanism for transmission to the server.

An exemplary configuration enabling various exercise systems to communicate over a Wide Area Network (WAN), such as the Internet, for multi-player operation is illustrated in Fig. 10. Specifically, this configuration is substantially similar to the configuration described above for Fig. 9, and further includes a Corporate Host or Server 99 housed at a remote location. The Corporate Host facilitates communication over a WAN to other local area network servers having exercise systems residing on those networks. Local server 98 communicates with and transmits to the Corporate Host, via the WAN, the direction, speed, and other information relevant to game play or exercise received from computer systems 70 residing on its local network. The Corporate Host coordinates exchange of data with

each local server in communication with the host and ensures that the local servers send and receive the necessary information, via the WAN, to enable computer systems 70 residing on their respective networks to perform the simulation. The Corporate Host also sends and receives information from the local servers relating to changes in the virtual environment.

An alternative configuration whereby game play or exercise may be managed by a Corporate Host over a Wide Area Network (WAN) is illustrated in Fig. 11. Specifically, this configuration is similar to the configuration described above for Fig. 10, except that each exercise system 30 (e.g., computer/ mechanism pair 70, 80) communicates directly with Corporate Host 99 via the WAN. In essence, the configuration enables each computer system to exchange information over the WAN via host 99. In addition, the configurations described above for Figs. 10 and 11 may be combined so that the Corporate Host may communicate with a mix of local servers and exercise systems to facilitate communication between various exercise systems over the WAN for multi-player operation.

Another configuration wherein one of the computer systems 70 of an exercise system further serves as a Local Area Network (LAN) server is illustrated in Fig. 12. This configuration is similar to the configuration described above for Fig. 10, except that an exercise system 100 (e.g., computer/mechanism pair) further functions as a local server. Specifically, exercise system 100 is substantially similar to exercise systems 30, and essentially receives and distributes information to the other exercise systems residing on its local network. Exercise system 100 communicates with Corporate Host 99 over a wide area network (WAN) during game or exercise interaction in substantially the same manner described above to interface and provide other exercise systems or local area network servers in communication with host 99 with the proper information for the simulation.

The Local Area Network (LAN) Server and the Corporate Host computer systems described above may be implemented by any conventional computer systems having sufficient networking and/or communications capability to transfer data at a minimum rate of ten Megabits per second (MBPS).

An exemplary software architecture for multi-player operation to enable the computer system to control the virtual environment in response to user interaction is illustrated in Fig. 13. Initially, the software architecture is similar to the architecture described above for Fig. 7 except that the multi-player architecture utilizes data received from other exercise systems, via a local or wide area network as described above, to display users from those systems within the virtual environment as virtual competitors. Specifically, the software architecture includes a Communication Manager module 192, Game Manager module 182, Remote Object Manager module 194, Collision Manager module 186, Local Object Manager module 188 and Display Manager module 190. Computer system 70 is substantially similar to the computer system described above for Fig. 7 and includes an operating system (e.g., Windows 98, Windows NT, etc.) and a simulation development environment (e.g., SimStudio available from N-Dimension, Inc.) to provide an environment for execution of the software.

Computer system 70 is coupled to a communications medium 195, such as a local or wide area communications network, to receive data from other exercise systems. Communication Manager module 192 interfaces communications medium 195 to receive and transfer data, typically in the form of data packets. The communications medium may be implemented by any network and may utilize various protocols to transfer the data, such as User Datagram Protocol (UDP) or Transmission Control/Internet Protocol (TCP/IP). The Communications Manager module receives data from other exercise systems and distributes information to Game Manager module 182 (e.g., in the form of incoming game packets), Local Object Manager module 188 (e.g., in the form of an incoming collision packet) and Remote Object Manager module 194 (e.g., in the form of incoming object packets). The Communications Manager module further receives information from the Local Object Manager module (e.g., in the form of outgoing object packets) and Collision Manager module (e.g., in the form of an outgoing collision packet) for transmission over communications medium 195 to other exercise systems. Essentially, the Communications Manager module formats data for reception and transmission over the communications medium in accordance with the appropriate communications

protocol. Game Manager module 182 receives information from the various exercise mechanism sensors and input devices and the Remote and Local Object Manager modules, and is generally responsible for controlling game play or simulation (e.g., including providing summary feedback) and display of items in the virtual environment as described above. The sensor measurements are received via the wiring harness and hardware interface device as described above. The hardware interface device may also transmit signals to the exercise mechanism (e.g., to control a resistance mechanism). The Game Manager module processes the incoming game packet information and further distributes information to Local and Remote Object Manager modules 188, 194 (e.g., in the form of game or simulation status information) and Display Manager module 190 (e.g., in the form of display type information). The Remote Object Manager module processes the received status and incoming object packet information and maintains the position and status of users of the other exercise systems within the virtual environment. This module may further add or remove users from the virtual environment as users begin or end their workouts. The information relating to position, speed and other characteristics of the other users is transmitted to Collision Manager module 186.

Local Object Manager module 188 determines the position, speed and other characteristics of the local user (e.g., collision information relative to other users based on the received incoming collision packet information) within the virtual environment and provides that information to the Collision Manager module. The Local Object Manager module further provides information pertaining to the local user (e.g., in the form of an outgoing object packet) to the Communication Manager module for transmission to other exercise systems. The Collision Manager module processes the information received from the Remote and Local Object Manager modules and determines whether or not a collision has occurred (e.g., crashing into a virtual object) and the forces resulting from a collision (e.g., to assess user damages, point loss or other simulation parameters). The determined forces are returned to Local Object Manager module 188, while Local and Remote Object Manager modules 188, 194 each process and transmit information to Game Manager module 182 (e.g., information relating to game or simulation status) and Display Manager

module 190 (e.g., information relating to object position, orientation, status, etc.). The Collision Manager module further provides collision information (e.g., in the form of an outgoing collision packet) to the Communication Manager module for transmission to the other exercise systems.

The Game Manager module utilizes the received status information to update the simulation. The Display Manager module receives the display type and object information from the Game Manager and Remote and Local Object Manager modules and processes the information to display the virtual environment scene (e.g., including all of the users) on monitor 20 (Fig. 1a). Basically, the Display Manager module retrieves the scene geometry and textures from memory and processes the received user and object information to create the displayed image for the local user during the workout. In addition, the Display Manager module provides audio associated with that environment to the local user.

The manner in which computer system 70 processes information from the exercise mechanism and other exercise systems to perform an interactive simulation is illustrated, by way of example only, in Fig. 14. Specifically, a user selects a virtual environment and starts exercising at step 230. The computer system initiates the communications and associated handshaking to commence data transfer over a communications medium for the simulation. Communications Manager module 192 (Fig. 13) retrieves information of other exercise systems from the communications medium at step 232 and provides information to the Game Manager and Remote and Local Object Manager modules as described above. Game Manager module 182 receives the measurements and user interaction from the exercise mechanism via the hardware interface device at step 234 and provides information to the Display Manager and Remote and Local Object Manager modules as described above. The Remote and Local Object Manager modules, at step 236, determine the speed, position and other characteristics of objects and users within the virtual environment and provide that information to Collision Manager module as described above.

The Collision Manager module, at step 238, determines whether or not a collision has occurred based on the received information. If a collision has occurred, the Collision Manager module determines the forces resulting from that collision at

step 240 and returns information relating to the forces to the Local Object Manager module as described above. The Remote and Local Object Manager modules process and transmit information to the Game Manager module to update the simulation and to the Display Manager module for display of the virtual environment scene with associated audio at step 242. The Communications Manager module receives user and collision information from the Local Object Manager and Collision Manager modules, and transmits that information over the communications medium to the other exercise systems at step 244. This information enables display of the local user in the virtual environments of the other exercise systems. The workout status is ascertained by the Game Manager module, and if the local workout is determined to be complete (e.g., goal attained, time expired, local user terminates workout, etc.) at step 246, the Communications Manager module, at step 248, notifies the other exercise systems to remove the user from the virtual environment, while the Game Manager module provides summary feedback information to the local user and terminates the local workout. Otherwise, new information is retrieved from the exercise mechanism at step 232 and the above-described process is repeated.

The software for stand-alone and multi-player operation of computer system 70 is preferably implemented in the 'C' programming language, however, the software may be implemented by any commercially available and/or custom software implemented in any suitable computer language. The Communications Manager module for multi-player operation preferably utilizes a commercially available software library available from R-Time, Inc. to perform its functions, however, any commercially available and/or custom software may be utilized. In addition, the Display Manager module for stand-alone and multi-player operation preferably utilizes Diamondware Sound Tool Kit, a commercially available software library from Diamondware, Inc., to perform audio functions, however, any commercially available and/or custom software may be utilized.

Operation of the exercise system is described with reference to Fig. 1a. Initially, a user adjusts the distance from seat 24 to pedals 56, 57 by using quick-release mechanism 48 as described above. Subsequently, the user sits in seat 24

and begins pedaling. A game selection screen appears on monitor 20 presenting the user with a variety of exercises or games that may be selected. When making a selection, the user has the option of initiating either the stand-alone or the multi-player mode. The stand-alone and multi-player versions of the selected exercise or game are substantially similar, except that the user typically competes against the computer during stand-alone mode, while competing against other users, either in the same location or at remote locations around the world, during multi-player mode. The user further selects workout parameters or targets, such as the time interval for the workout or number of calories burned. The speed with which the user moves through the virtual environments is dependent upon the pedaling speed and the level of resistance/drag applied to flywheel 68. The level of resistance/drag may be varied by changing the position of tension adjustment handle 38, or the resistance may be varied by the resistance mechanism and computer system 70 based on the virtual environment as described above.

During the workout, the user manipulates inner frame 16 to steer through the virtual environment. For example, climbing is accomplished by pulling on handles 74, 174 to pivot the inner frame in an upward direction, while pushing back on handles 74, 174 pivots the inner frame in a downward direction to simulate diving. Further, the handles may be manipulated to move the inner frame transversely relative to the outer frame to simulate turning. Buttons 76, 176 are typically utilized to fire weapons or perform other acts appropriate to the selected game or exercise.

Once the workout target is reached, the workout terminates. In the individual or stand-alone mode, the exercise system terminates the workout. However, during multi-player mode, the local user is removed from the virtual environment, while other users maintain the simulation. Summary statistics (e.g., calories burned, average revolutions per minute, miles traveled, etc.) are typically displayed on monitor 20 at the completion of the workout.

It will be appreciated that the embodiments described above and illustrated in the drawings represent only a few of the many ways of implementing a virtual-realty exercise system and method.

The suspension bars, brackets, elevated bar and outer frame bars of the outer frame may be of any quantity, shape or size and may be constructed of any suitable materials. The elevated bar may be oriented at any suitable angle. The outer frame may be configured in any fashion suitable to suspend the inner frame. The inner frame rails and bars may be of any quantity, shape or size, and may be constructed of any suitable materials. The inner frame may be configured in any fashion and include any type of seat or other structure for supporting the user. The inner frame may be of any shape or size, and may be suspended from the outer frame via any mechanism enabling movement of the inner frame in at least one degree of freedom. The inner frame may be utilized without an outer frame and may be suspended from any type of structure enabling inner frame motion, such as a pole, ceiling, wall, etc. The monitor, computer system, audio speakers, sensors and other system components may be disposed on the exercise system at any location and in any fashion.

The pivot assembly supports may be of any quantity, shape or size and may be constructed of any suitable materials. The platform may be configured to interface the elevated bar at any suitable angle. The roll and pitch pivot sensors may be implemented by any conventional encoder, potentiometer or other device capable of measuring roll and pitch angles of inner frame motion. For example, the roll and pitch pivot sensors may each be implemented by variable potentiometers or resistance devices that measure electrical impedance to indicate inner frame motion. In particular, a reference electrical signal is transmitted through the sensor potentiometer, whereby rotation of a sensor pulley-type member controls the amount of impedance or resistance encountered by the reference signal. The sensor pulley member is connected to the stationary pulley member via a belt, whereby inner frame motion causes rotation of the sensor pulley member as described above and controls the amount of potentiometer impedance or resistance. The electrical signal from the potentiometer is provided to the computer system for comparison with the reference signal to determine the amount of impedance or resistance encountered by the reference signal. The determined impedance or resistance is proportional to the

amount of sensor pulley member rotation, thereby providing an indication of the pitch or roll angle of inner frame motion.

The roll and pitch pivot sensor belts may be implemented by any belt, band, cord, chain or other suitable device. The pivot assembly components may be arranged in any fashion to enable inner frame motion and measurement of that motion in at least one degree of freedom. Further, the pivot assembly may be implemented by any device enabling inner frame motion in at least one degree of freedom and measurement of that motion. Moreover, the fastener interfacing the inner frame to the pivot assembly may be implemented by any conventional or other fastening device enabling adjustment of inner frame position relative to the outer frame.

The pedal assembly may be replaced with any other exercise or rehabilitative equipment, such as for stair climbing, cross-country skiing, treadmill, etc. The flywheel and chain ring may be of any shape or size, and may be constructed of any suitable materials. The flywheel and chain ring may be interconnected via any suitable devices, such as a belt, band, chain, common axle, etc. The pedal assembly may include any type of quick-release or locking mechanism enabling adjustment of the assembly to accommodate variously sized users. The quick-release mechanism may include any type of conventional or other handle. The proximity sensor may be implemented by any magnetic or other type of sensor for detecting the pedaling rate. The metallic plate may be of any shape or size, and may be disposed on the chain ring in any fashion. Further, other items detectable by the sensors may be disposed on the chain ring or other pedal assembly components to detect the pedaling rate.

The tension adjustment mechanism may apply resistance to the flywheel or directly to the chain ring via any suitable devices, such as hydraulic, pneumatic, mechanical, electrical or electro-mechanical devices. The strap may be disposed on the exercise system via any clasping or fastening techniques, and may extend about the exercise system in any path or fashion. The tension adjustment cam may be implemented by any device that can control tension within or manipulate the strap. The strap may be implemented by any device such as a belt, band, cord, chain, etc., having sufficient frictional properties to impede flywheel rotation. The tension

mechanism may be disposed in any fashion on the exercise system, and may include any type of conventional or other handle to control strap tension.

The tension adjustment sensor may be implemented by any conventional encoder, potentiometer or other device capable of measuring cam rotation. For example, the tension adjustment sensor may be implemented by a variable potentiometer or resistance device to measure electrical impedance and indicate cam rotation and strap tension in substantially the same manner described above for the roll and pitch pivot sensors. The tension adjustment sensor belt may be implemented by any belt, band, cord, chain or other suitable device. The cam may be utilized without the strap, whereby the computer system may control resistance based on cam manipulation via a resistance mechanism as described above. Alternatively, a desired resistance or level may be entered into the computer system via an input device, whereby the computer system controls the resistance mechanism to provide the desired resistance. The resistance mechanisms or strap may be coupled to the flywheel, chain ring or any other pedal assembly component to control pedaling resistance.

The computer system may be of any quantity (e.g., at least one), and may be disposed in any fashion and at any location on the exercise system. Alternatively, the computer system may be disposed external of the system, but connected to the exercise system components. The computer system may be implemented by any conventional or other computer or processing system. The computer system may include any commercially available and/or custom software performing the functions described above, whereby the custom software may be implemented in any suitable computer language. The software hierarchy and algorithms may be modified in any fashion capable of performing the above-described functions.

The computer system may include any conventional hardware interface device to transmit and receive data from the exercise mechanism. The interface device may further generate pulse counts from the various sensors for processing by the computer system. The computer system may be connected to the exercise mechanism components via a wiring harness, direct wiring or any other conventional or other connection techniques. The exercise system may include any type of input

devices, such as buttons, mouse, joystick, keyboard, voice recognition, etc., disposed at any suitable location. It is to be understood that the software of the present invention may be developed by one of ordinary skill in the computer arts based on the functional descriptions contained herein and the flow charts illustrated in the drawings. In addition, the descriptions herein of software performing particular functions generally refer to the computer system performing those functions under software control.

The exercise system may communicate with other systems via a local area network (LAN), wide area network (WAN) or any other communications medium. The LAN may include any quantity of exercise systems, while the Corporate Host may communicate with any quantity of servers and exercise systems. The communications medium may employ any suitable communications protocol. The exercise systems may be configured in any fashion to enable communication between the exercise systems over a communications medium. Further, an exercise system may further serve as a local area network server or a corporate host to facilitate information exchange between a plurality of exercise systems for multi-player operation. The local area servers and hosts may be implemented by any conventional or other computer or processing system having communications capabilities for transferring data. The exercise systems may be housed at, and communicate with each other from, any location (e.g., a home, gym facility, etc.).

The exercise system may be of any size, and may accommodate any quantity of users and corresponding monitors. The exercise system may simulate any virtual environment and/or game, and may be programmed by a user with various parameters (e.g., duration, calories burned, distance, points, etc.) to customize a workout. The exercise system may receive any input from a user, and include monitoring devices to provide the user with any type of physical (e.g., heart rate, blood pressure, etc.) or other summary feedback (e.g., calories burned, miles traversed, duration of workout, etc.) information.

It is to be understood that the terms "forward", "backward", "right", "left", "top", "bottom", "up", "down", "front", "rear", "side", "fore", "aft", "length" and the like are

used herein merely to describe points of reference and do not limit the present invention to any specific orientation or configuration.

The form of the embodiments described above is illustrative of the principles of the present invention which include, but are not limited to, the following summary:

1) An exercise system having a suspended frame including an exercise device, whereby the frame and exercise device are manipulable by a user to simulate traversal of a virtual environment.

1a) An exercise device with two or more degrees of freedom that utilizes an extended universal joint that supports a hung weight and that provides different amounts of effort for motions in one axis of rotation as opposed to motions in the orthogonal axis.

1b) A user suspended from a universal joint and interacting with handles mounted to an external frame.

1c) An inner frame or gondola containing additional exercise components.

2) A method of varying resistance to a pedaling mechanism via a strap that is tensioned by varying the angle of a user support structure such that pointing upwards (e.g., uphill) results in greater pedaling effort, and pointing downwards (e.g., downhill) results in less pedaling effort.

3) A modular leg exercise assembly that may be removed and exchanged with other mechanisms that provide for biomechanically correct motion in users with varying states of lower body disability.

3a) A pedal system with varying resistance.

3b) A driven pedal system with variable speed.

3c) A driven leg flexion system.

3d) A leg flexion system that utilizes the relative motion of an inner frame with respect to an outer frame (e.g., driven by the arms of the user) to move the legs through their range of motion.

4) A computer system including software that introduces events into a game and then tracks the time and degree of reaction for later biomechanical analysis.

4a) A computer system integrated with an exercise machine that takes into account the mass of the device.

4b) A computer system including an interactive program that subsequently modifies the introduction of cues into the game based on previous data gathered.

5) A rehabilitation device.

6) Exercise machines connected in a network via a host mechanism with virtually no perceived time delay.

7) Exercise machines connected in a network via the Internet.

8) The capability to play a competitive game with virtually zero perceived latency.

From the foregoing description, it will be appreciated that the invention makes available a novel virtual-reality exercise system and method wherein an inner frame having an exercise device is suspended from an outer frame via a pivot assembly having a plural degree of freedom hinge to facilitate navigation and traversal through a simulated environment in response to user manipulation of the inner frame and exercise device.

Having described preferred embodiments of a new and improved virtual-reality exercise system and method, it is believed that other modifications, variations and changes will be suggested to those skilled in the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims.

What Is Claimed Is:

1. An exercise system for facilitating a user workout and simulating traversal through a virtual environment in response to manipulation of said system by a user during said workout comprising:

a support structure;

a display for displaying said virtual environment to said user;

an exercise assembly manipulable by said user to facilitate said workout and said simulated traversal of said virtual environment;

a pivot assembly including a hinge having first and second degrees of freedom, wherein said hinge is coupled to said support structure to suspend said exercise assembly from said support structure and pivot said exercise assembly in said first and second degrees of freedom in response to user manipulation of said exercise assembly;

a pivot control mechanism manipulable by said user and coupled to said support structure to control pivoting of said exercise assembly in said first and second degrees of freedom in accordance with user manipulation, wherein said control mechanism is manipulated by said user in response to conditions within said virtual environment; and

a processor to simulate and adjust said virtual environment in response to manipulation of said exercise assembly and pivot control mechanism.

2. The system of claim 1 wherein said hinge is responsive to forces of said exercise assembly and control mechanism manipulation for pivoting said exercise assembly in said first and second degrees of freedom, and wherein force required by said hinge to pivot said exercise assembly in said second degree of freedom is greater than the force required by said hinge to pivot said exercise assembly in said first degree of freedom.

3. The system of claim 1 wherein said hinge includes:

a roll assembly to selectively pivot said exercise assembly in said first degree of freedom in response to said manipulation of said exercise assembly and pivot control mechanism; and

a pitch assembly to selectively pivot said exercise assembly in said second degree of freedom in response to said manipulation of said exercise assembly and pivot control mechanism; and

a coupling rod disposed between and coupled to said pitch and roll assemblies.

4. The system of claim 3 wherein said roll assembly includes:

roll assembly supports;

a roll shaft disposed through said roll assembly supports, wherein a proximal end of said coupling rod is rotatably coupled to said roll shaft; and

a roll sensor to measure rotation of said coupling rod relative to said roll shaft, thereby providing an indication of manipulation of said exercise assembly in said first degree of freedom;

wherein said measured coupling rod rotation is provided to said processor to adjust said virtual environment in response to manipulation of said exercise assembly in said first degree of freedom.

5. The system of claim 3 wherein said pitch assembly includes:

pitch assembly supports;

a pitch shaft disposed through said pitch assembly supports and rotatably coupled to a distal end of said coupling rod;

a pitch sensor to measure rotation of said pitch assembly relative to said pitch shaft, thereby providing an indication of manipulation of said exercise assembly in said second degree of freedom;

wherein said measured pitch assembly rotation is provided to said processor to adjust said virtual environment in response to manipulation of said exercise assembly in said second degree of freedom.

6. The system of claim 1 wherein said exercise assembly includes:

an exercise mechanism removably attached to said exercise assembly and manipulable by said user to facilitate said workout and simulated traversal of said virtual environment; and

a resistance device coupled to said exercise mechanism to impede exercise mechanism manipulation by controlling resistance applied to said exercise mechanism.

7. The system of claim 6 wherein said exercise mechanism includes:

a cycling device having pedals manipulable by said user; and

a rate sensor to measure a rate of pedaling by said user;

wherein said measured pedaling rate is provided to said processor to adjust said virtual environment in response to manipulation of said exercise mechanism.

8. The system of claim 7 wherein said cycling device includes:

a flywheel; and

a chain ring coupled to said flywheel and having said pedals manipulable by said user.

9. The system of claim 8 wherein said resistance device includes:

a cam having a handle manipulable by said user;

a strap traversing said exercise assembly and engaging said cam and extending about said flywheel to apply frictional forces to said flywheel in response to manipulation of said handle; and

a tension sensor to measure manipulation of said cam, wherein said measured cam manipulation is provided to said processor to adjust said virtual environment in response to manipulation of said cam;

wherein said cam adjusts a path length of said strap to control strap tension and frictional forces applied to said flywheel, thereby controlling resistance applied to said exercise mechanism, and wherein said path length is further adjusted in response to manipulation of said exercise assembly in said second degree of freedom to automatically control said resistance applied to said exercise mechanism.

10. The system of claim 6 wherein said processor controls said resistance device to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

11. The system of claim 10 wherein said resistance device includes an alternator.

12. The system of claim 10 wherein said resistance device includes a magnetic particle brake.

13. The system of claim 10 wherein said resistance device includes an electrically conductive disk coupled to said exercise mechanism, wherein said disk is disposed within a magnetic field to produce currents within said disk that, in combination with said magnetic field, impede disk rotation and apply resistance to said exercise mechanism.

14. The system of claim 10 wherein said resistance device includes a servomotor.

15. The system of claim 1 wherein said processor includes:

an interface device for receiving signals from said exercise assembly indicating measured manipulation of said exercise assembly;

simulation management means for controlling simulation and display of said virtual environment in accordance with said signals received by said interface device;

object means for determining and maintaining positions of virtual objects within said virtual environment;

user means for determining and maintaining positions of said user within said virtual environment in accordance with said signals received by said interface device;

collision means for determining presence of collisions between said virtual objects and said user and forces resulting from said collisions based on said determined virtual object and user positions; and

display means for displaying said virtual environment in accordance with said determined virtual object and user positions and providing corresponding audio.

16. The system of claim 1 wherein said processor is coupled to at least one other exercise system via a communications network and includes:

an interface device for receiving signals from said exercise assembly indicating measured manipulation of said exercise assembly;

communication means for transferring and receiving information from said communications network;

simulation management means for controlling simulation and display of said virtual environment in accordance with said signals received by said interface device and information received by said communication means;

object means for determining and maintaining positions of users of said at least one other exercise system within said virtual environment in accordance with said information received by said communication means;

user means for determining and maintaining positions of said user within said virtual environment in accordance with said signals received by said interface device;

collision means for determining presence of collisions between said user and users of said at least one other exercise system and forces resulting from said collisions based on said determined positions; and

display means for displaying said virtual environment in accordance with said determined positions and providing corresponding audio.

17. The system of claim 1 wherein said processor is coupled to at least one other exercise system via a server system residing on a communications network.

18. The system of claim 17 wherein said communications network is a local area network.

19. The system of claim 17 wherein said communications network is a wide area network.

20. The system of claim 1 wherein said processor is coupled to at least one other exercise system via a local area communications network and includes a server

system residing on that network, and wherein said processor is further coupled to one or more exercise systems via a second server system residing on a wide area communications network.

21. An exercise system for facilitating a user workout and simulating traversal through a virtual environment in response to manipulation of said system by a user during said workout comprising:

a support structure;

a display for displaying said virtual environment to said user;

an exercise assembly manipulable by said user to facilitate said workout and said simulated traversal of said virtual environment;

a pivot assembly including a hinge responsive to forces of said exercise assembly manipulation for pivoting said exercise assembly in first and second degrees of freedom, wherein force required by said hinge to pivot said exercise assembly in said second degree of freedom is greater than the force required by said hinge to pivot said exercise assembly in said first degree of freedom, and wherein said hinge is coupled to said support structure to suspend said exercise assembly from said support structure and pivot said exercise assembly in said first and second degrees of freedom in response to user manipulation of said exercise assembly;

a pivot control mechanism manipulable by said user and coupled to said support structure to control pivoting of said exercise assembly in said first and second degrees of freedom in accordance with user manipulation, wherein said control mechanism is manipulated by said user in response to conditions within said virtual environment; and

a processor to simulate and adjust said virtual environment in response to manipulation of said exercise assembly and pivot control mechanism.

22. The system of claim 21 wherein said hinge includes:

a roll assembly to selectively pivot said exercise assembly in said first degree of freedom in response to said manipulation of said exercise assembly and pivot control mechanism; and

a pitch assembly to selectively pivot said exercise assembly in said second degree of freedom in response to said manipulation of said exercise assembly and pivot control mechanism; and

a coupling rod disposed between and coupled to said pitch and roll assemblies.

23. The system of claim 21 wherein said exercise assembly includes:

an exercise mechanism removably attached to said exercise assembly and manipulable by said user to facilitate said workout and simulated traversal of said virtual environment; and

a resistance device coupled to said exercise mechanism to impede exercise mechanism manipulation by controlling resistance applied to said exercise mechanism.

24. The system of claim 23 wherein said processor controls said resistance device to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

25. A method of facilitating a user workout on an exercise system and simulating traversal through a virtual environment in response to manipulation of said system by a user during said workout, wherein said exercise system includes an exercise assembly for facilitating said user workout, said method comprising the steps of:

(a) displaying said virtual environment to said user;

(b) suspending said exercise assembly from a support structure via a hinge having first and second degrees of freedom;

(c) pivoting said exercise assembly in said first and second degrees of freedom in response to user manipulation of said exercise assembly to facilitate said workout and said simulated traversal of said virtual environment;

(d) controlling pivoting of said exercise assembly in said first and second degrees of freedom in accordance with user manipulation of a pivot control mechanism, wherein said pivot control mechanism is manipulated by said user in response to conditions within said virtual environment; and

(e) simulating and adjusting said virtual environment in response to manipulation of said exercise assembly and pivot control mechanism.

26. The method of claim 25 wherein step (c) further includes:

(c.1) selectively pivoting said exercise assembly in said first and second degrees of freedom via said hinge in response to forces of said exercise assembly and control mechanism manipulation, wherein force required by said hinge to pivot said exercise assembly in said second degree of freedom is greater than the force required by said hinge to pivot said exercise assembly in said first degree of freedom.

27. The method of claim 25 wherein said hinge includes a roll assembly and a pivot assembly, and step (c) further includes:

(c.1) selectively pivoting said exercise assembly in said first degree of freedom via said roll assembly in response to said manipulation of said exercise assembly and pivot control mechanism; and

(c.2) selectively pivoting said exercise assembly in said second degree of freedom via said pitch assembly in response to said manipulation of said exercise assembly and pivot control mechanism.

28. The method of claim 27 wherein step (c.1) further includes:

(c.1.1) determining manipulation of said exercise assembly in said first degree of freedom by measuring pivoting motion of said roll assembly and adjusting said virtual environment in accordance with said determined manipulation.

29. The method of claim 27 wherein step (c.2) further includes:

(c.2.1) determining manipulation of said exercise assembly in said second degree of freedom by measuring pivoting motion of said pitch assembly and adjusting said virtual environment in accordance with said determined manipulation.

30. The method of claim 25 wherein said exercise assembly includes an exercise mechanism manipulable by said user and a resistance device coupled to said exercise mechanism, and step (b) further includes:

(b.1) removably attaching said exercise mechanism to said exercise assembly to facilitate said workout and simulated traversal of said virtual environment; and

(b.2) impeding exercise mechanism manipulation by controlling resistance applied to said exercise mechanism by said resistance device.

31. The method of claim 30 wherein said exercise mechanism includes a cycling device having pedals manipulable by said user, and step (b) further includes:

(b.3) measuring a rate of pedaling by said user to adjust said virtual environment in response to manipulation of said exercise mechanism.

32. The method of claim 31 wherein said cycling device includes a flywheel and a chain ring coupled to said flywheel and having said pedals manipulable by said user, and said resistance device includes a cam having a handle manipulable by said user and a strap traversing said exercise assembly and engaging said cam and extending about said flywheel to apply frictional forces to said flywheel in response to manipulation of said handle, wherein step (b.2) further includes:

(b.2.1) adjusting a path length of said strap via manipulation of said cam to control strap tension and frictional forces applied to said flywheel, thereby controlling resistance applied to said exercise mechanism;

(b.2.2) measuring manipulation of said cam to adjust said virtual environment in response to manipulation of said cam; and

(b.2.3) adjusting said path length in response to manipulation of said exercise assembly in said second degree of freedom to automatically control said resistance applied to said exercise mechanism.

33. The method of claim 30 wherein step (b.2) further includes:

(b.2.1) controlling said resistance device to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

34. The method of claim 33 wherein said resistance device includes an alternator, and step (b.2.1) further includes:

(b.2.1.1) controlling said alternator to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

35. The method of claim 33 wherein said resistance device includes a magnetic particle brake, and step (b.2.1) further includes:

(b.2.1.1) controlling said magnetic particle brake to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

36. The method of claim 33 wherein said resistance device includes an electrically conductive disk coupled to said exercise mechanism, wherein said disk is disposed within a magnetic field to produce currents within said disk that, in combination with said magnetic field, impede disk rotation and apply resistance to said exercise mechanism, and step (b.2.1) further includes:

(b.2.1.1) controlling said disk and magnetic field to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

37. The method of claim 33 wherein said resistance device includes a servomotor, and step (b.2.1) further includes:

(b.2.1.1) controlling said servomotor to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

38. The method of claim 25 wherein step (e) includes:

(e.1) receiving signals from said exercise assembly indicating measured manipulation of said exercise assembly;

(e.2) controlling simulation and display of said virtual environment in accordance with said signals received from said exercise assembly;

(e.3) determining and maintaining positions of virtual objects within said virtual environment;

(e.4) determining and maintaining positions of said user within said virtual environment in accordance with said signals received from said exercise assembly;

(e.5) determining presence of collisions between said virtual objects and said user and forces resulting from said collisions based on said determined virtual object and user positions; and

(e.6) displaying said virtual environment in accordance with said determined virtual object and user positions and providing corresponding audio.

39. The method of claim 25 wherein said exercise system is coupled to at least one other exercise system via a communications network, and step (e) includes:

(e.1) receiving signals from said exercise assembly indicating measured manipulation of said exercise assembly;

(e.2) transferring and receiving information from said communications network;

(e.3) controlling simulation and display of said virtual environment in accordance with said signals received from said exercise assembly and information received from said communications network;

(e.4) determining and maintaining positions of users of said at least one other exercise system within said virtual environment in accordance with said information received from said communications network;

(e.5) determining and maintaining positions of said user within said virtual environment in accordance with said signals received from said exercise assembly;

(e.6) determining presence of collisions between said user and users of said at least one other exercise system and forces resulting from said collisions based on said determined positions; and

(e.7) displaying said virtual environment in accordance with said determined positions and providing corresponding audio.

40. The method of claim 25 wherein step (e) further includes:

(e.1) coupling said exercise system to at least one other exercise system via a server system residing on a communications network.

41. The method of claim 25 wherein step (e) further includes:

(e.1) coupling said exercise system to at least one other exercise system via a server system residing on a local area communications network.

42. The method of claim 25 wherein step (e) further includes:

(e.1) coupling said exercise system to at least one other exercise system via a server system residing on a wide area communications network.

43. The method of claim 25 wherein said exercise system includes a server system residing on a local area communications network, and step (e) further includes:

(e.1) coupling said exercise system to at least one other exercise system residing on said local area communications network via said server system; and

(e.2) coupling said exercise system to one or more exercise systems via a second server system residing on a wide area communications network.

44. A method of facilitating a user workout on an exercise system and simulating traversal through a virtual environment in response to manipulation of said exercise system by a user during said workout, wherein said exercise system includes an exercise assembly for facilitating said user workout, said method comprising the steps of:

(a) suspending said exercise assembly from a support structure; and

(b) pivoting said exercise assembly in first and second degrees of freedom in response to user manipulation of said exercise assembly to facilitate said workout and said simulated traversal of said virtual environment, wherein force required to pivot said exercise assembly in said second degree of freedom is greater than the force required to pivot said exercise assembly in said first degree of freedom.

45. The method of claim 44 wherein said exercise assembly includes an exercise mechanism manipulable by said user and a resistance device coupled to said exercise mechanism, and step (b) further includes:

(b.1) removably attaching said exercise mechanism to said exercise assembly to facilitate said workout and simulated traversal of said virtual environment; and

(b.2) impeding exercise mechanism manipulation by controlling resistance applied to said exercise mechanism by said resistance device.

46. The method of claim 45 wherein step (b.2) further includes:

(b.2.1) controlling said resistance device to apply a particular resistance to said exercise mechanism in accordance with conditions in said virtual environment.

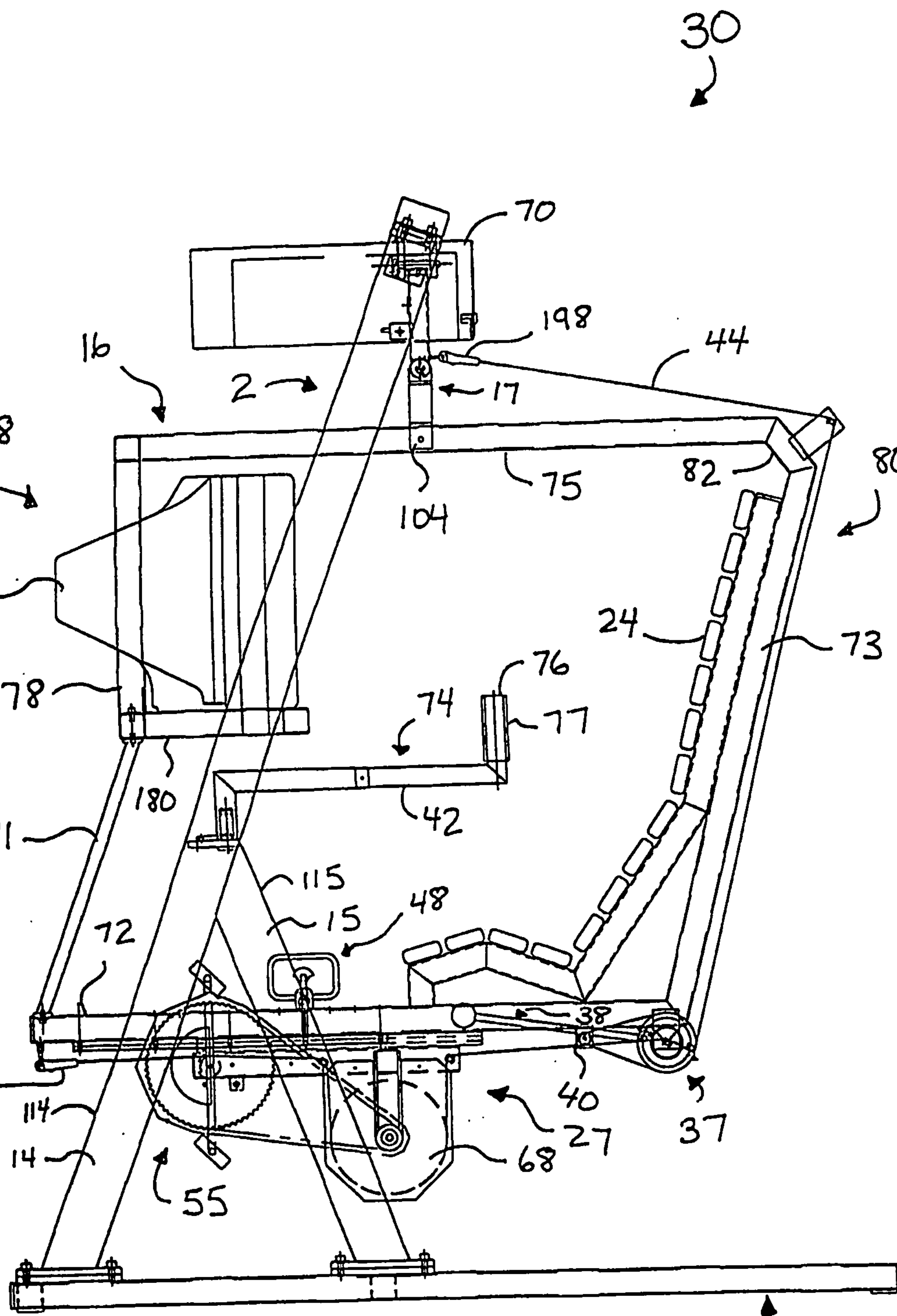
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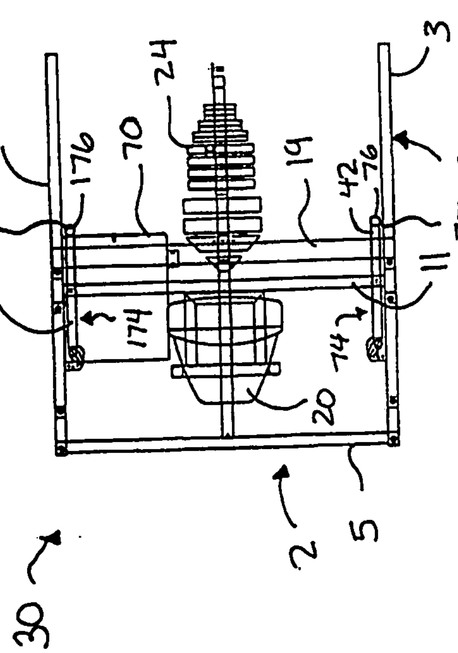
FIG.1A

FIG.1B



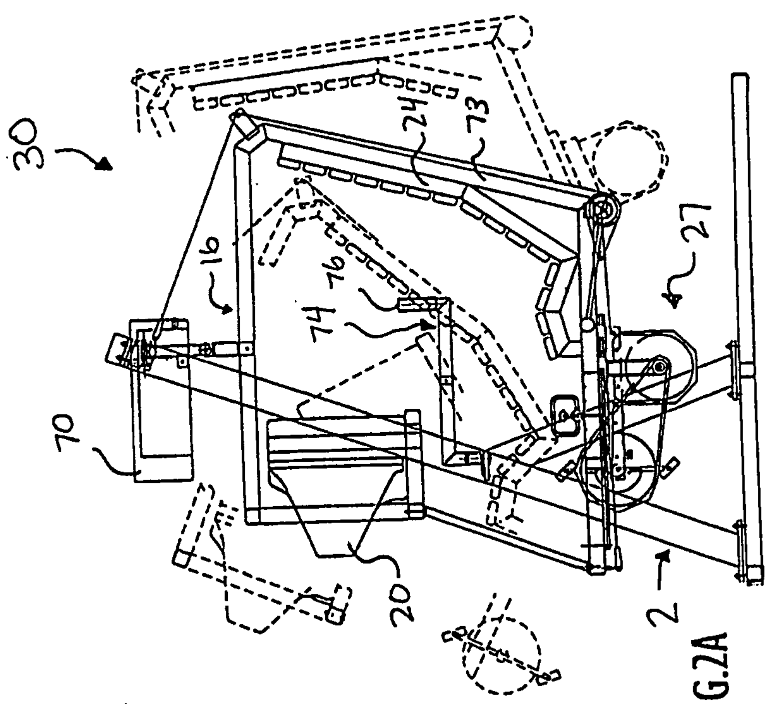


FIG.2A

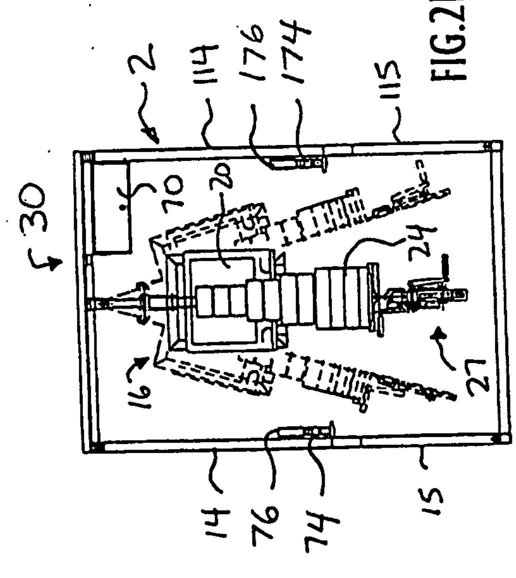


FIG.2B

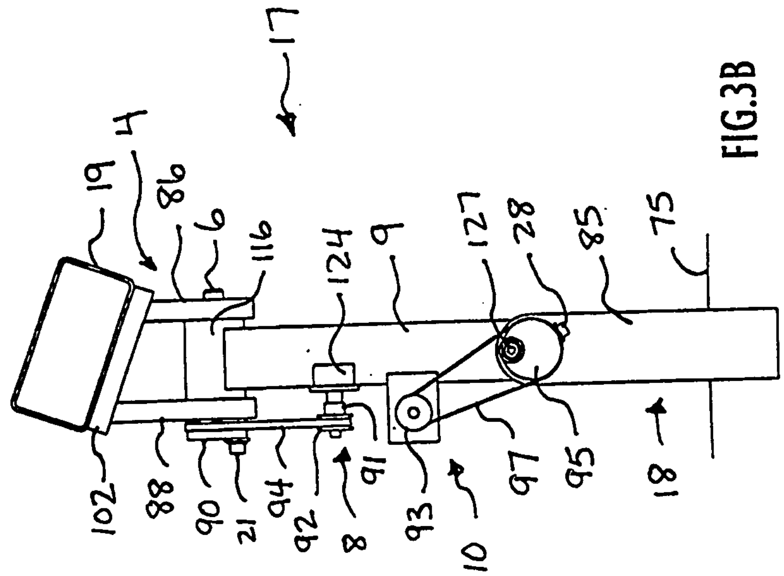

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FIG.3B

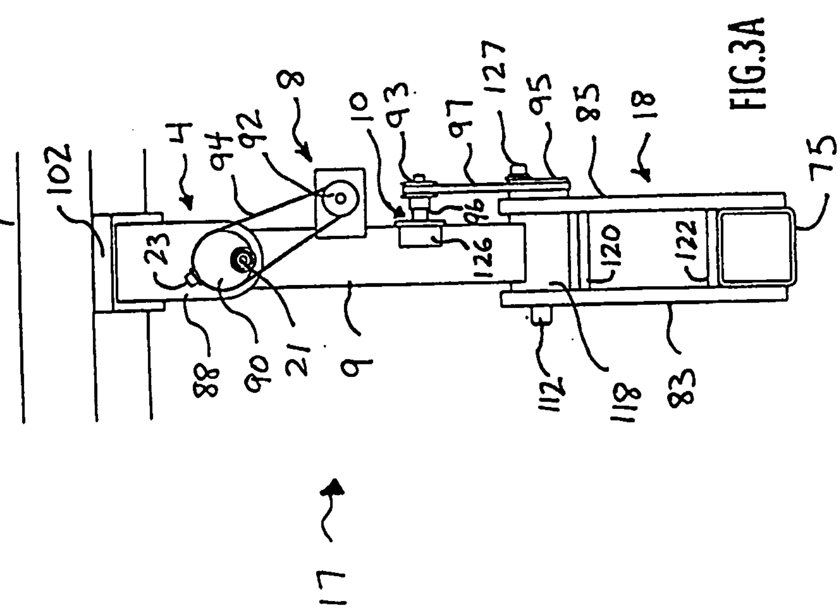
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FIG.3A

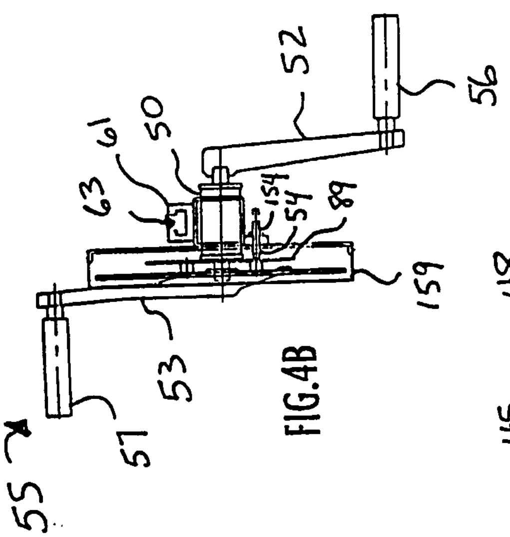

FIG.4B

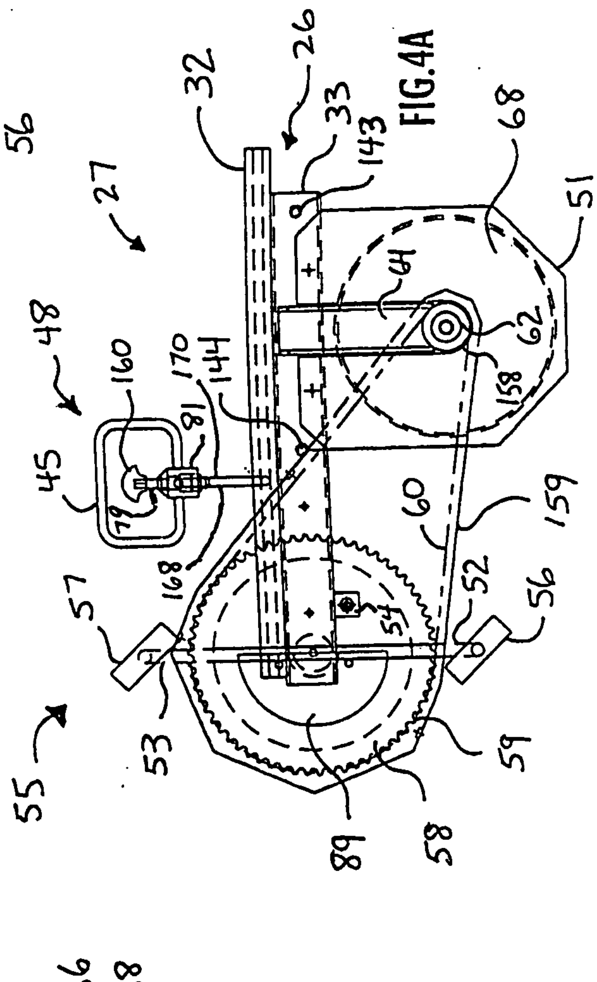

FIG.4A

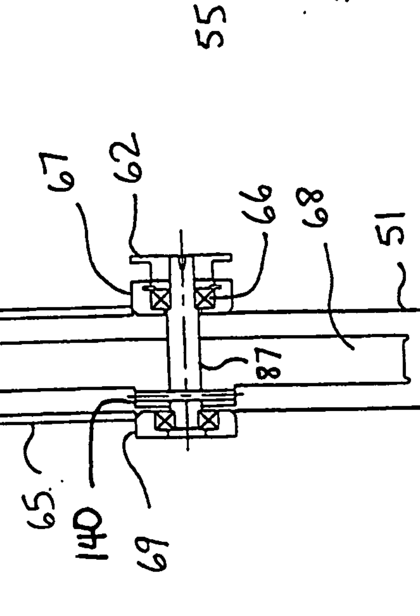

FIG.4C

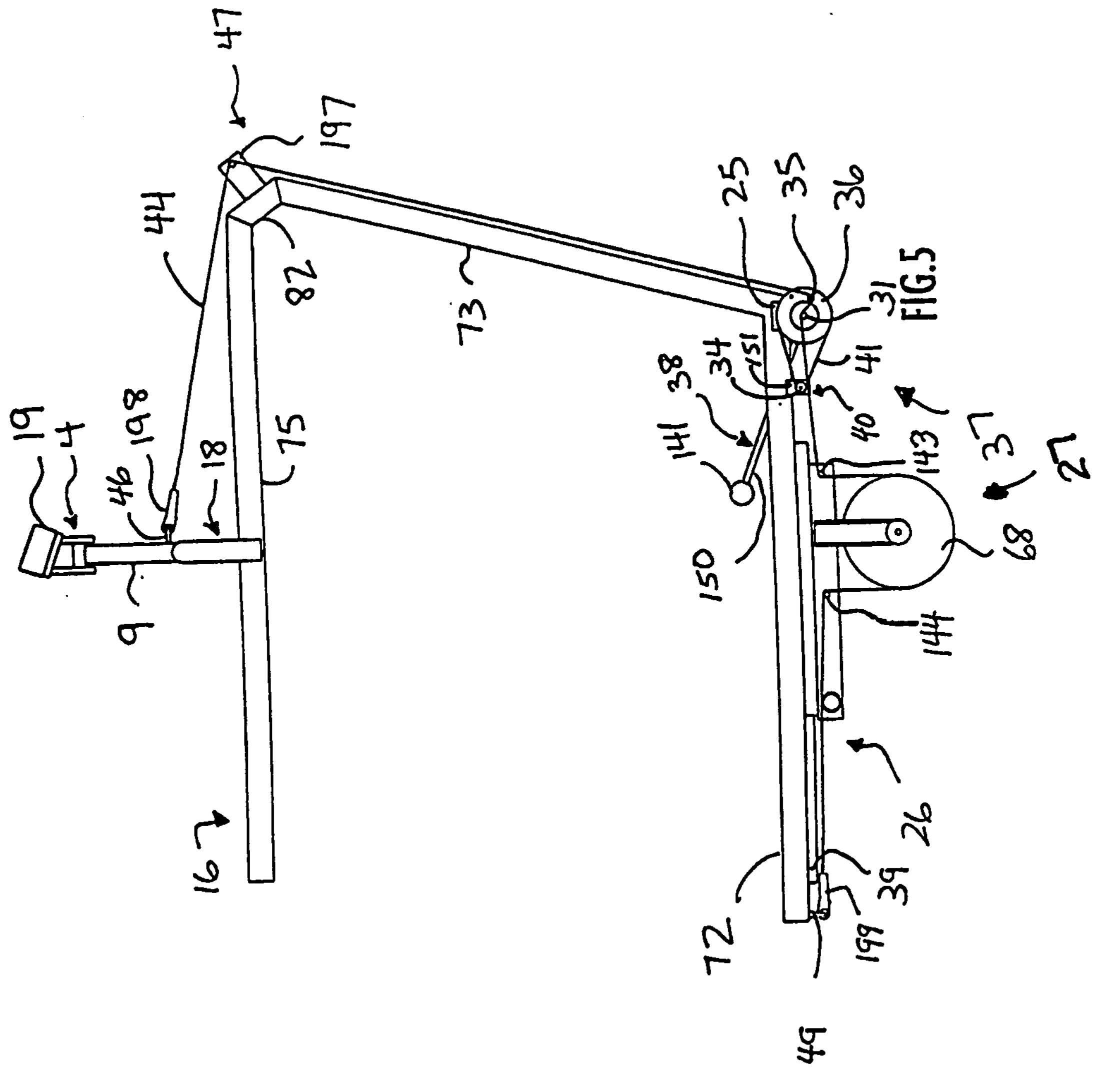
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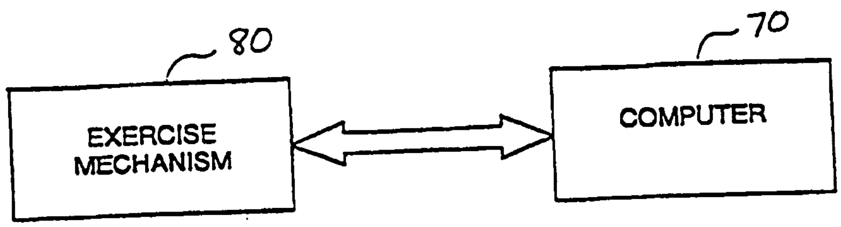
FIG.5

Fig. 6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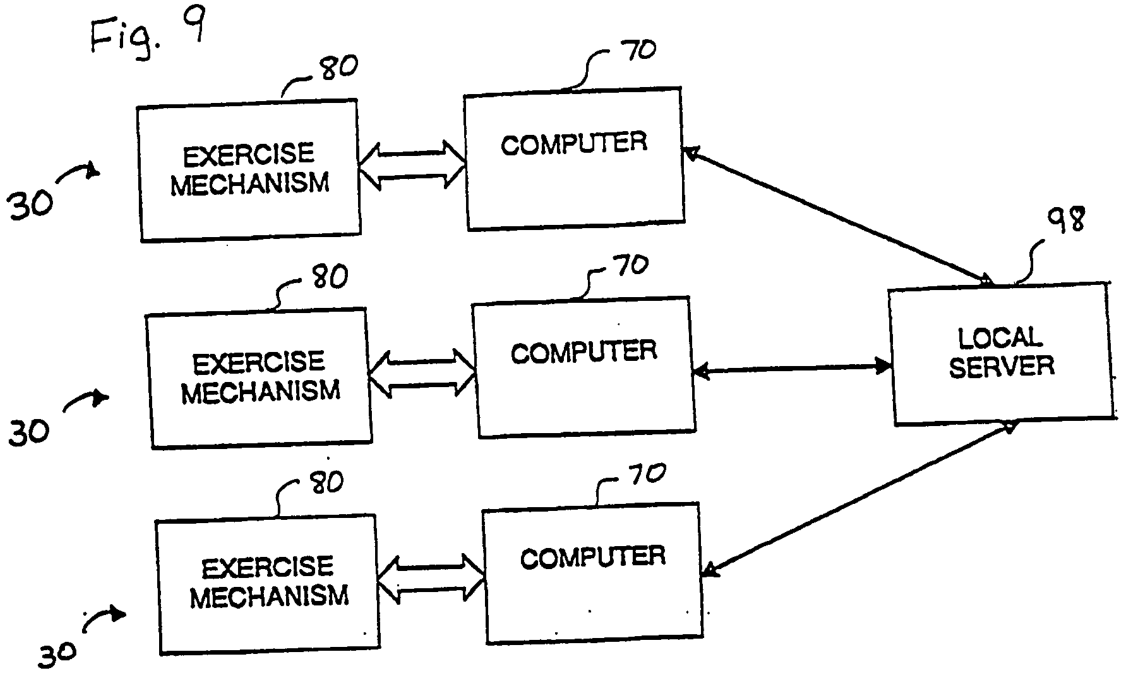
70
EXERCISE MECHANISM
COMPUTER

Fig. 9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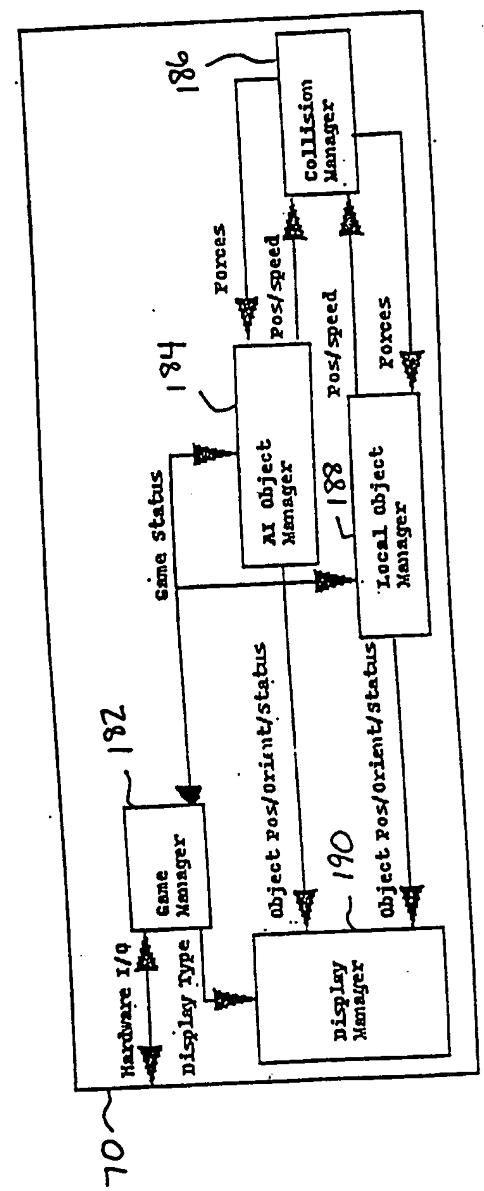
EXERCISE MECHANISM
COMPUTER
30
98
LOCAL SERVER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Collision Manager
Forces
Pos/speed
184
AI Object Manager
Game Status
188
Local Object Manager
Pos/speed
Forces
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Game Manager
Object Pos/Orient/Status
190
Object Pos/Orient/Status
Hardware I/O
Display Type
Display Manager
70

Fig. 7

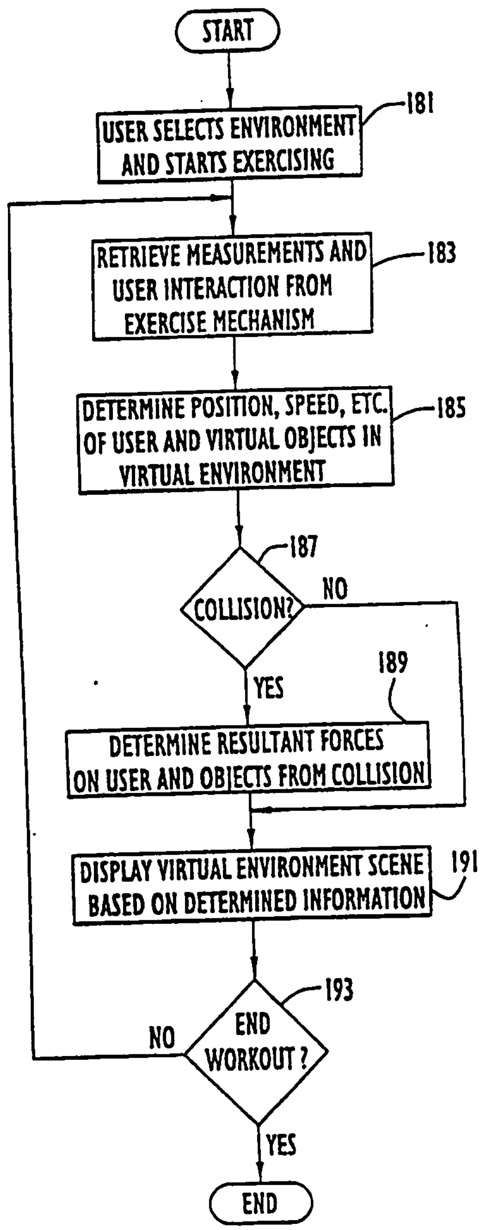

START
USER SELECTS ENVIRONMENT AND STARTS EXERCISING
181
RETRIEVE MEASUREMENTS AND USER INTERACTION FROM EXERCISE MECHANISM
183
DETERMINE POSITION, SPEED, ETC. OF USER AND VIRTUAL OBJECTS IN VIRTUAL ENVIRONMENT
185
187
COLLISION?
NO
YES
189
DETERMINE RESULTANT FORCES ON USER AND OBJECTS FROM COLLISION
DISPLAY VIRTUAL ENVIRONMENT SCENE BASED ON DETERMINED INFORMATION
191
193
END WORKOUT ?
NO
YES
END

FIG.8

Fig. 10

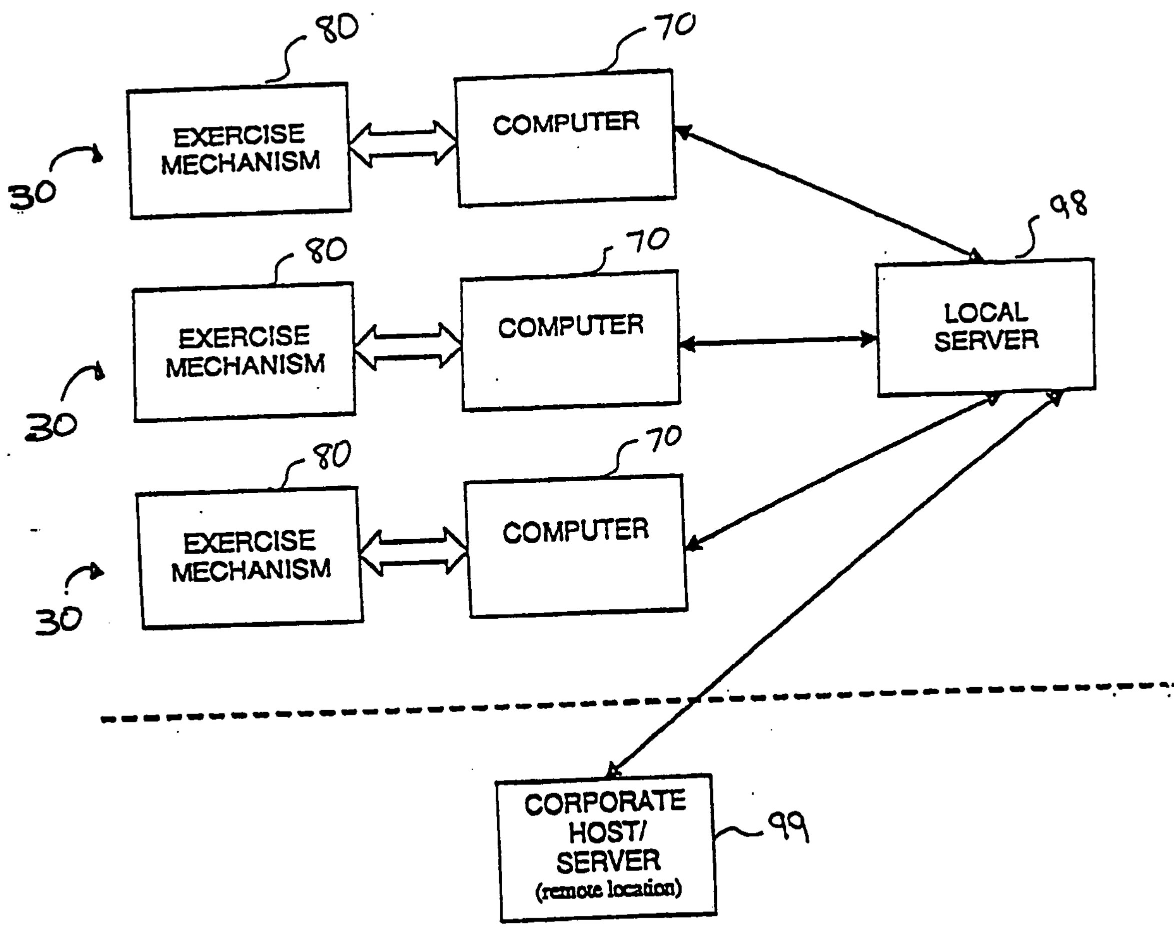

80
70
EXERCISE MECHANISM
COMPUTER
30
98
80
70
EXERCISE MECHANISM
COMPUTER
LOCAL SERVER
30
80
70
EXERCISE MECHANISM
COMPUTER
30
CORPORATE HOST/ SERVER (remote location)
99

Fig.11

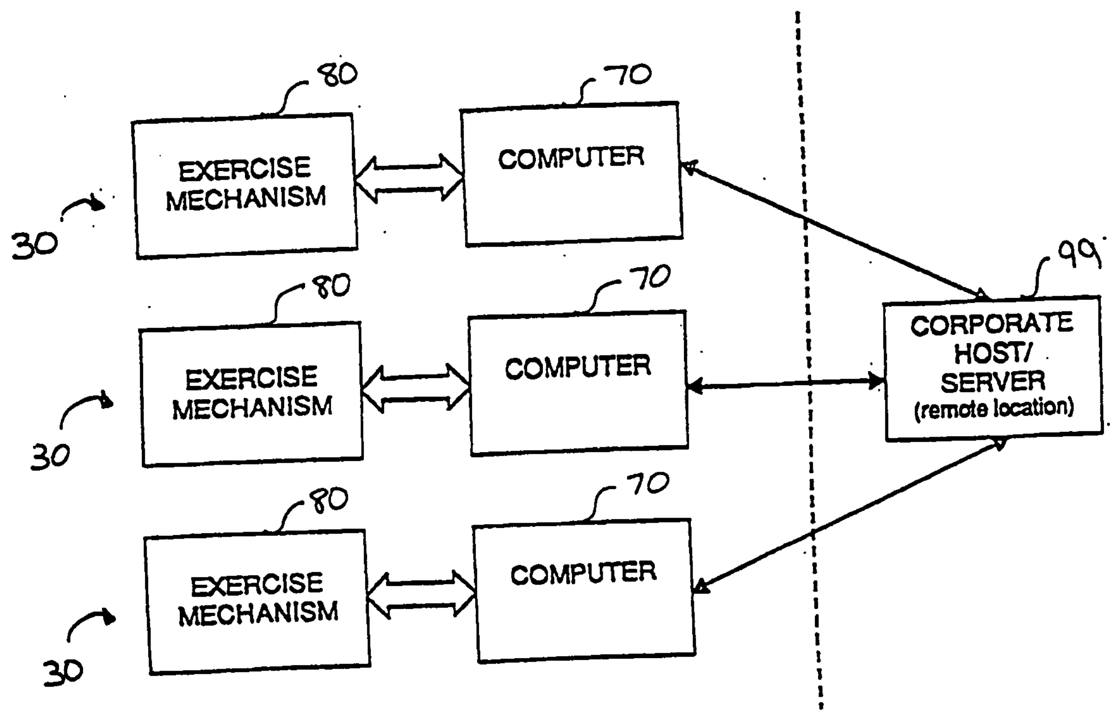
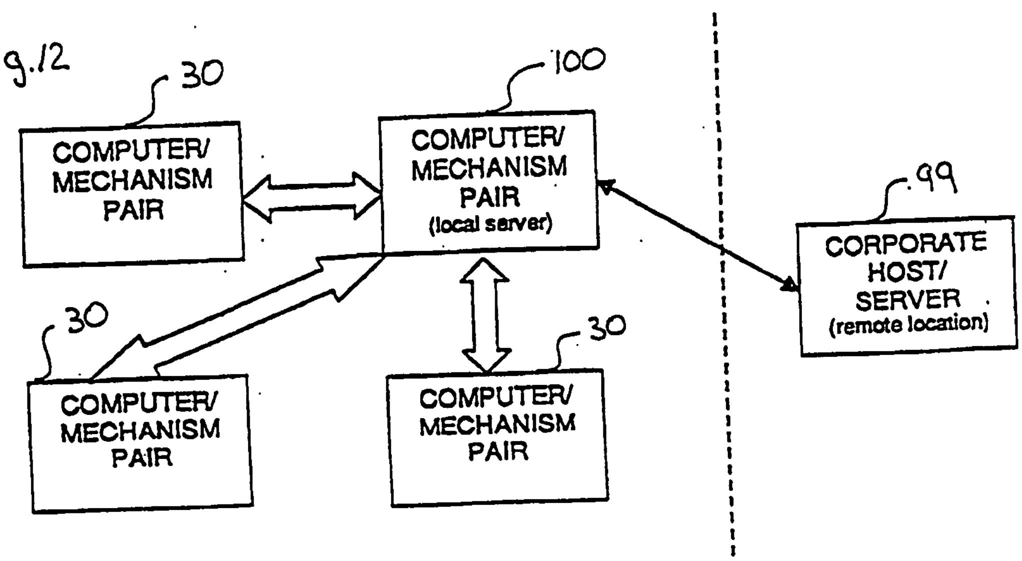

80
70
EXERCISE MECHANISM
COMPUTER
30
80
70
99
EXERCISE MECHANISM
COMPUTER
CORPORATE HOST/ SERVER (remote location)
30
80
70
EXERCISE MECHANISM
COMPUTER
30

Fig.12


30
100
COMPUTER/ MECHANISM PAIR
COMPUTER/ MECHANISM PAIR (local server)
99
CORPORATE HOST/ SERVER (remote location)
30
30
COMPUTER/ MECHANISM PAIR
COMPUTER/ MECHANISM PAIR

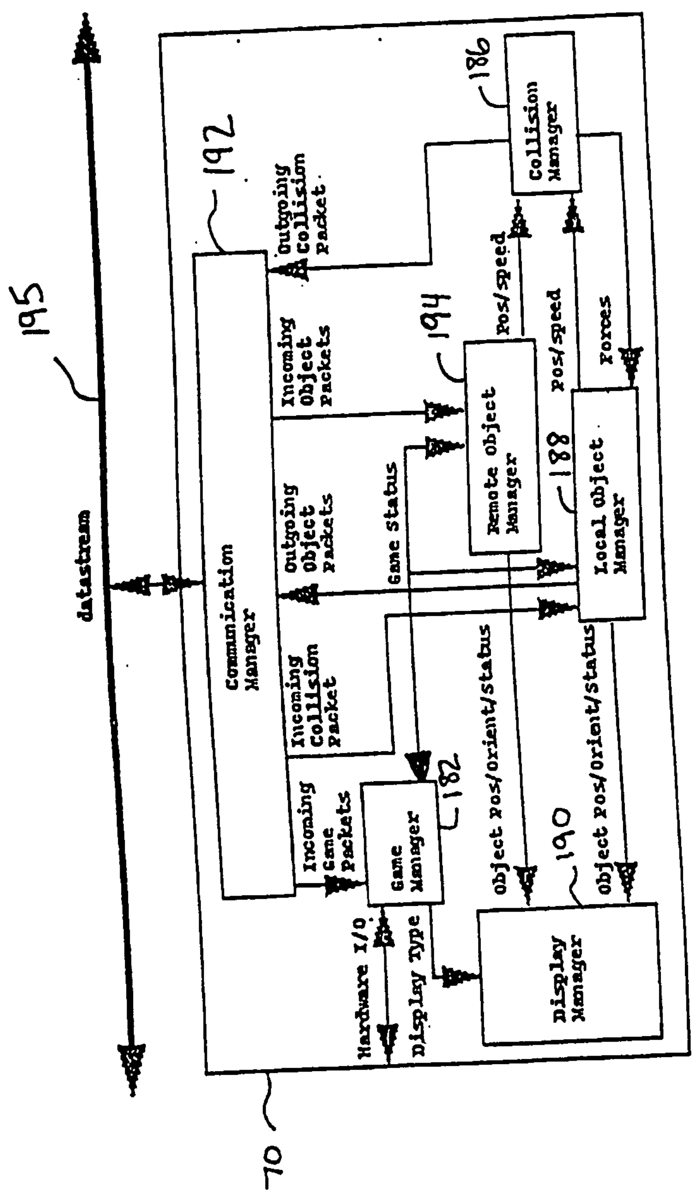

195
datastream
192
Communication Manager
Outgoing Collision Packet
Incoming Object Packets
Outgoing Object Packets
Incoming Collision Packet
Incoming Game Packets
186
Collision Manager
194
Remote Object Manager
188
Local Object Manager
Pos/speed
Pos/speed
Forces
Game Status
182
Game Manager
Object Pos/orient/status
Object Pos/orient/status
190
Display Manager
Hardware I/O
Display Type
70

Fig. 13

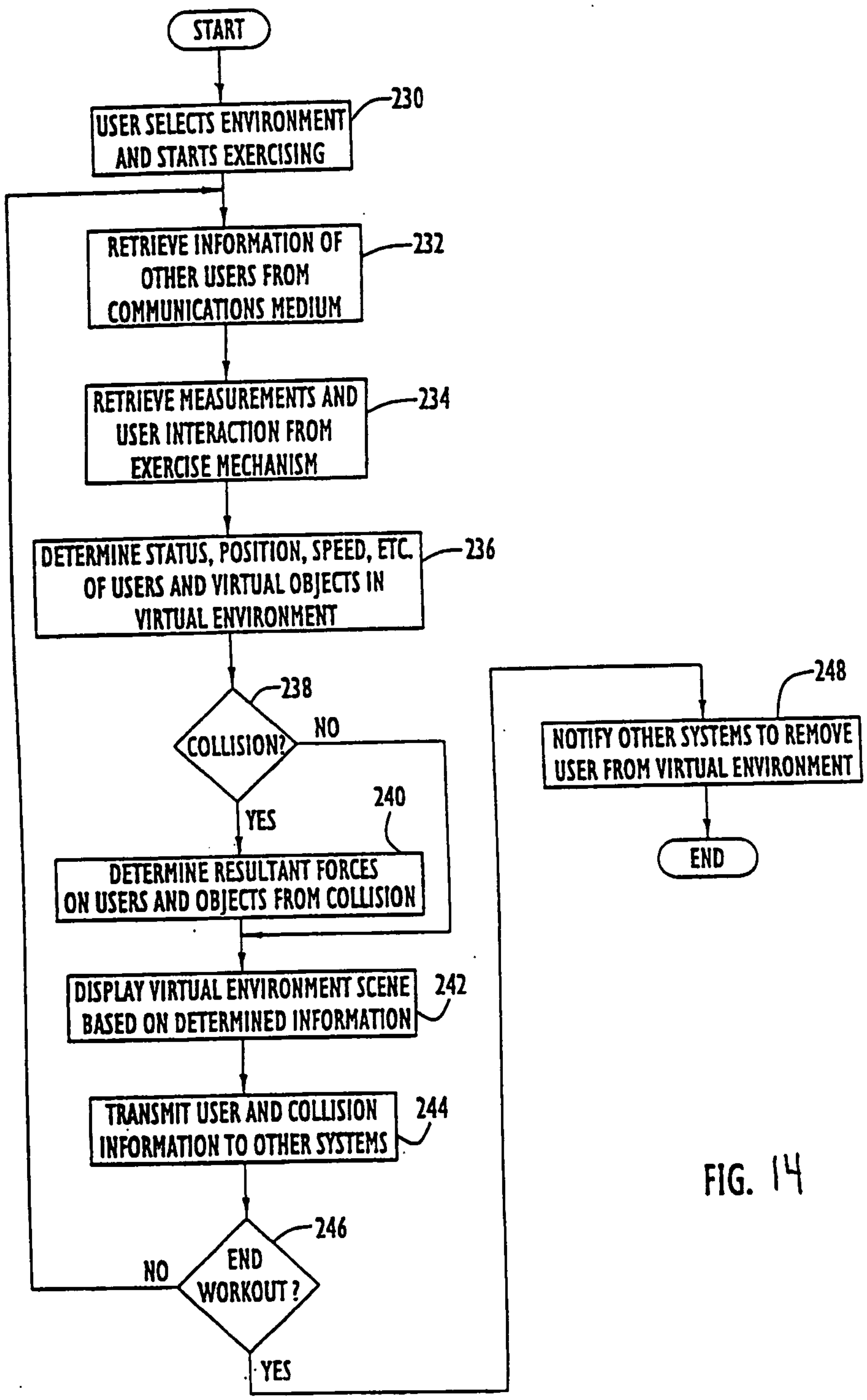

START
USER SELECTS ENVIRONMENT AND STARTS EXERCISING
230
RETRIEVE INFORMATION OF OTHER USERS FROM COMMUNICATIONS MEDIUM
232
RETRIEVE MEASUREMENTS AND USER INTERACTION FROM EXERCISE MECHANISM
234
DETERMINE STATUS, POSITION, SPEED, ETC. OF USERS AND VIRTUAL OBJECTS IN VIRTUAL ENVIRONMENT
236
COLLISION?
238
NO
YES
DETERMINE RESULTANT FORCES ON USERS AND OBJECTS FROM COLLISION
240
DISPLAY VIRTUAL ENVIRONMENT SCENE BASED ON DETERMINED INFORMATION
242
TRANSMIT USER AND COLLISION INFORMATION TO OTHER SYSTEMS
244
END WORKOUT?
246
NO
YES
NOTIFY OTHER SYSTEMS TO REMOVE USER FROM VIRTUAL ENVIRONMENT
248
END

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/07952

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G09B 9/00
US CL : 482/4
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 482/4

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US 5,980,256 A (CARMEIN) 09 November 1999, see entire document.	1-46
A, P	US 5,890,995 A (BOBICK et al.) 06 April 1999, see entire document.	1-46
A	US 5,792,031 A (ALTON) 11 August 1998, see entire document.	1-46

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
14 JUNE 2000

Date of mailing of the international search report
03 JUL 2000

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